LAMPIRAN A. NERACA MASSA

Kapasitas produksi = 15.000 ton/tahun

Operasi pabrik = 300 hari kerja/ tahun

$$\text{Kapasitas produksi/jam} = 150.000\,\frac{\text{ton}}{\text{tahun}}\,\text{x}\,\frac{1\ \text{tahun}}{300\ \text{hari}}\,\text{x}\,\frac{1\ \text{hari}}{24\ \text{jam}}\,\text{x}\,\frac{1000\ \text{kg}}{1\ \text{ton}}$$

= 20.833,33 kg/jam

Basis perhitungan = 1000 kg/jam

Kapasitas Produksi Basis = 3507,09 kg/jam

$$\text{Faktor Pengali} = \frac{Kapsitas\ Sebenarnya}{Kapasitas\ \ Basis} = \frac{20833{,}33\ kg/jam}{3507{,}09\ kg/jam} = 5{,}9403$$

Maka untuk memproduksi Urea Formaldehid 150.000 ton/tahun dibutuhkan bahan baku sebesar 5.940,2521 kg/jam

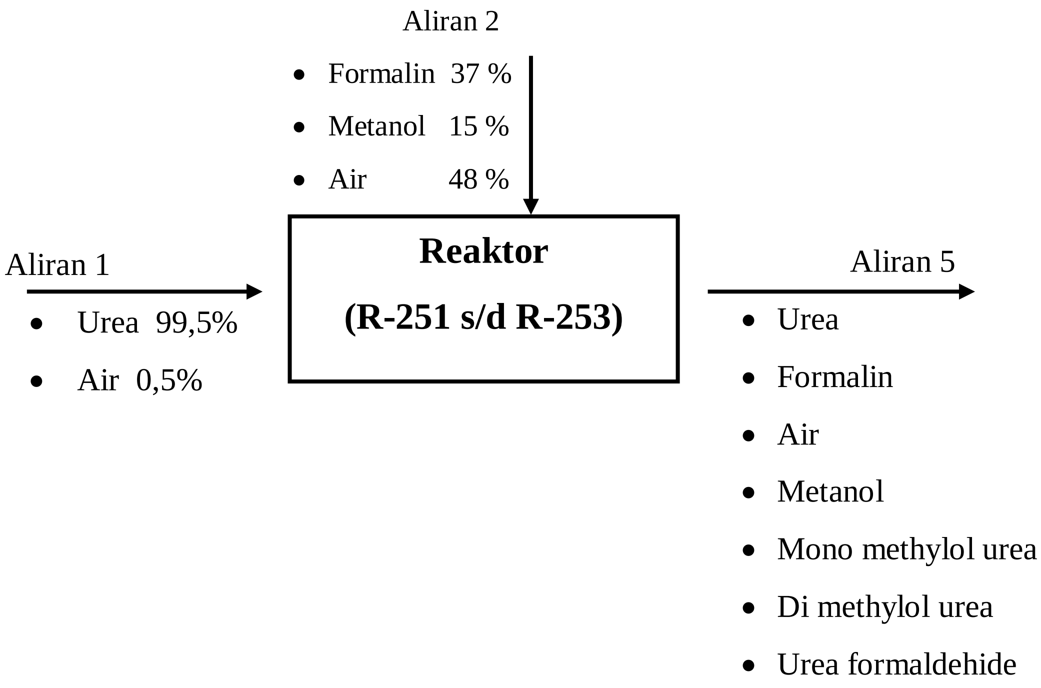
Bahan Baku Urea = 1000 kg/jam x 5,9403

= 5.940,2521 kg/jam

= 42.770 ton/tahun

1. Reaktor (R-251 s/d R-253)

Fungsi : Mengkonversikan urea dan formalin menjadi Urea Formaldehid dengan pengaturan pH larutan reaktan



Kondisi Operasi :

Temperatur : 100 ^oC dan 40 ^oC

Tekanan : 1 atm

pH : 8 dan 2,9

Waktu reaksi :

- Reaksi 1 dan 2 : 30 menit
- Reaksi 3 : 60 menit

Konversi :

- Reaksi 1 dan 2 : 98%
- Reaksi 3 : 99%

- **Input**

Tabel LA.1 Komposisi Bahan baku (Aliran 1)

Komponen	Massa (kg/jam)	Mol (Kmol/jam)	Kadar (%)
Urea	5.910,5508	98,5091	99,5
Air	29,7012	1,6501	0,5
Total	5.940,2521		100

Tabel LA.2 Komposisi Bahan baku (Aliran 2)

Komponen	Massa (kg/jam)	Mol (Kmol/jam)	Kadar (%)
Formalin	5.910,5509	197,0184	37
Metanol	2.396,1693	74,8803	15
Air	7.667,7417	425,9856	48
Total	15.974,4618		100

- **Output**

Konversi rx : 98%

Reaksi 1 :

	$CO(NH_2)_2$	+	CH_2O	→	NH2-CO-HN-CH2OH
Mula2 :	98,5091		197,0184		
Reaksi :	96,5390		96,5390		96,5390
Sisa :	1,9707		100,4794		96,5390

Konversi rx : 98%

Reaksi 2 :

	NH_2-CO-HN-CH_2OH +	CH_2O	→ CH_2OH-HN-CO-HN-CH2OH
Mula2 :	96,5390	100,4794	
Reaksi :	94,6082	94,6082	94,6082
Sisa :	1,9308	5,8711	94,6082

Konversi rx : 99%

Reaksi 3 :

	$C_3H_8N_2O_3$ +	$C_3H_8N_2O_3$	→ $C_6H_{14}O_5N_4$ +	H_2O
Mula2 :	94,6082	94,6082		
Reaksi :	93,6621	93,6621	93,6621	93,6621
Sisa :	0,9461	0,9461	93,6621	93,6621

❖ **Aliran 3**

Dari 3 reaksi di atas dapat dihitung massa keluaran pada aliran 3

- Urea

  Massa = 1,9707 kmol/jam x 60 kg/kmol = 118,211 kg/jam
- Formalin

  Massa = 5,8711kmol/jam x 30 kg/kmol = 176,1344 kg/jam
- Mono Methylol Urea

  Massa = 1,9308kmol/jam x 90 kg/kmol = 173,7702 kg/jam
- Di Methylol Urea

  Massa = 0,9461kmol/jam x 120 kg/kmol = 173,7702 kg/jam

  = 2 x173,7702 kg/jam

  = 227,0597 kg/jam
- Urea Formaldehid

  Massa = 93,6621kmol/jam x 222 kg/kmol = 20.792,9940 kg/jam
- Air

  Massa = 93,6621kmol/jam x 18 kg/kmol = 1.685,9184 kg/jam

  Massa Air = massa air (urea) + Massa Air(formalin) + Massa Air(rx)

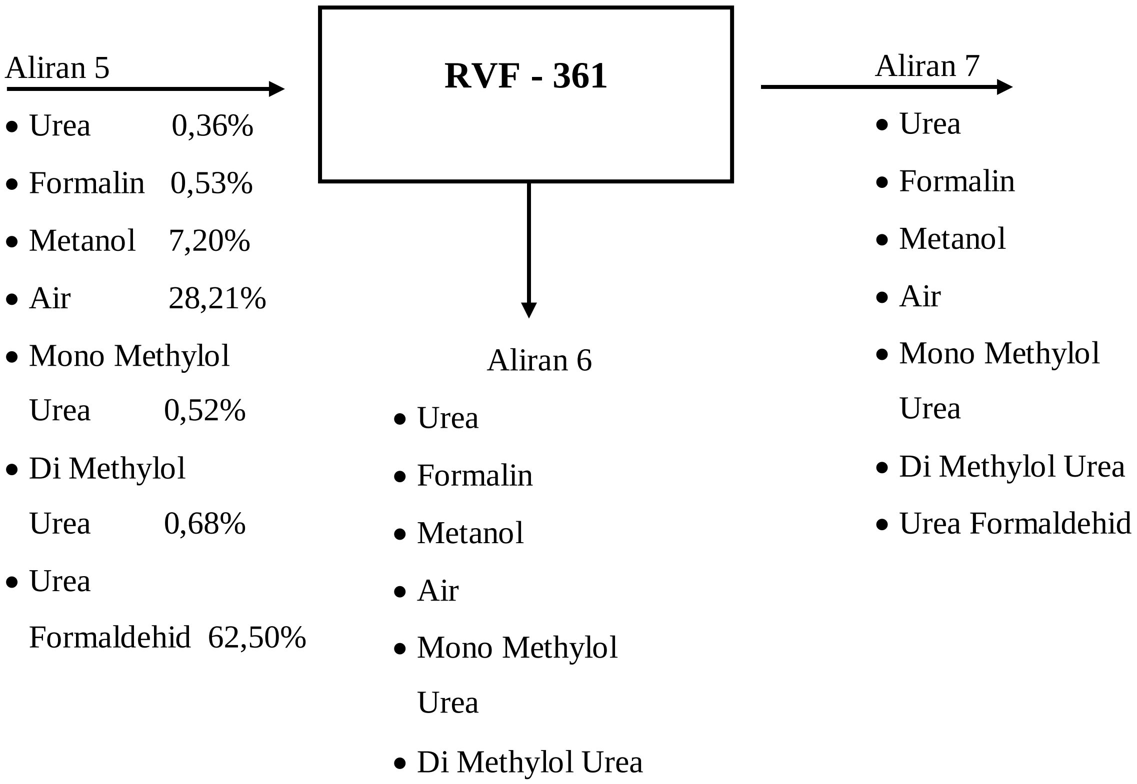
  = 29,7013 + 7.667,7416 + 1.685,9184 = 9.383,36 kg/jam

Tabel LA.3 Neraca Massa Reaktor (R-251 s/d R-253)

Komponen	BM	Masuk (Kg/jam)						Keluar (Kg/jam)	
		Aliran 1		Aliran 2		Hasil Reaksi		Aliran 3	
		Massa	%	Massa	%	Massa	%	Massa	%
Urea	60	5.910,551	99,5					118,211	0,36
Formalin	30			5.910,551	37			176,134	0,53
Metanol	32			2.396,169	15			2.396,169	7,20
Air	18	29,701	0,5	7.667,742	48			9.383,361	28,21
$C_2H_6N_2O_2$	90							173,770	0,52
$C_3H_8N_2O_3$	120					11.352,986	100	227,060	0,68
$C_6H_{14}N_4O_4$	222							20.792,994	62,50
Sub Total		5.940,252	100	15.974,462	100	11.352,986	100	33.267,700	100
Total		**33.267,700**						**33.267,700**	

2. Rotari Vakum Filter (RVF-361)

Fungsi : Memisahkan padatan Urea Formaldehid dari cairan impuritis



Tabel LA.4 Densitas Campuran Liquid dan Solid Aliran 6

Komponen	Wujud	Kadar (%)	Densitas murni (kg/m^3)	Densitas Sesuai Kadar (kg/m^3)
Urea	Liquid	0,36	1,23	0,4371
Formaldehid		0,53	0,72	0,3812
Metanol		7,20	792	5.704,5304
Air		28,21	990	27.923,5647
Mono methylol urea		0,52	750	391,7543
Di methylol urea		0,68	750	511,8923
Urea formaldehid	Cake	62,50	750	46.876,5365

❖ **Rumus Densitas sesuai Kadar(%)**

- **Densitas sesuai Kadar(%)** = Kadar per Komponen X Densitas murni
- **Densitas Campuran Liquid** = ∑(Densitas Sesuai kadar pada Liquid)
  = 34.532,5600 kg/m^3
- **Densitas Campuran Cake** = ∑(Densitas Sesuai Kadar pada Cake)
  = 46.876,5365 kg/m^3

➢ Pada kekeringan *cake* yang dihasilkan memiliki kelembaban. Kelembaban pada *cake* dapat ditentukan dengan persamaan berikut:

$$M = S\left(\frac{\rho}{\rho_S}\right) x \left(\frac{X}{1-X}\right)$$

(Brown,hal : 225)

Keterangan rumus :

- X = Porosity = 0,7 (Jenis Porous ceramic,spesial) (walas, Tabel 11.6)

TABLE 11.6. Porosities and Permeabilities of Some Filter Media

Porosity (%)	
Wedge wire screen	5–10
Perforated sheet	20
Wire mesh:	
Twill weave	15–25
Square	30–35
Porous plastics, metals, ceramics	30–50
Crude kieselguhr	50–60
Porous ceramic, special	70
Membranes, plastic foam	80
Asbestos/cellulose sheets	80
Refined filter aids (diatomaceous earth expanded perlite)	80–90
Paper	60–95
Scott plastic foam	97
Permeability, $10^{12}K_p$ (m^2) (compare Eq. (11.22))	
Filter aids	
Fine	0.05–0.5
Medium	1–2
Coarse	4–5
Cellulose fibre pulp	1.86
Cellulose fibre + 5% asbestos	0.34
Filter sheets	
Polishing	0.017
Fine	0.15
Clarifying	1.13
Sintered metal	
3 μm pore size	0.20
8 μm pore size	1.0
28 μm pore size	7.5
75 μm pore size	70

(Purchas, 1981; Walas, 1988).

- ρ_f = densitas filtrat = 34.532,5600 kg/m^3
- ρ_s = *densitas cake* =46.876,5365 kg/m^3
- S = Residual saturation = 0,025 (Brown, Pers 179)

Sehingga,

M = 0,0429 kg/jam

- Asumsi Konsentrasi Liquid pada umpan sama dengan liquid yang tertinggal pada cake

Komponen	% Liquid di aliran 8	Massa (kg/jam)	Massa liquid pada cake (kg/jam)
Urea	0,95	118,2110	0,0407
Formaldehid	1,41	176,1344	0,0607
Metanol	19,21	2.396,1693	0,8254
Air	75,22	9.383,3614	3,2323
Mono methylol urea	1,39	173,7702	0,0599
Di methylol urea	1,82	227,0597	0,0782

- Dari tabel diatas telah mendapatkan massa liquid yang terkandung dalam cake dengan cara seperti rumus dibawah ini:

- **Output**
- **Aliran 7**

Massa Liquid pada Cake = M(kelembaban pada cake) X % Liquid di Aliran 8

- Urea

  Massa Liquid Urea pada Cake =0,0429 kg/jam X 0,95%

  = 0,0407 kg/jam

- Formalin

  Massa Liquid Formalin pada Cake =0,0429 kg/jam X 1,41%

  = 0,0607 kg/jam

- Metanol
- Massa Liquid Metanol pada Cake =0,0429 kg/jam X 19,21%

  = 0,8254 kg/jam

- Air

  Massa Liquid Air pada Cake =0,0429 kg/jam X 75,22%

  = 3,2323 kg/jam

- Mono methylol Urea

  Massa Liquid pada Cake =0,0429 kg/jam X 1,39%

  = 0,0599 kg/jam

- Di methylol Urea

  Massa Liquid pada Cake =0,0429 kg/jam X 1,82%

  = 0,0782 kg/jam

Tabel LA.5 Neraca Massa Rotari Vakum Filter (RVF-361)

Komponen	**Masuk (Kg/jam)**		**Keluar (Kg/jam)**			
	Aliran 5		**Aliran 6**		**Aliran 7**	
	Massa	**%**	**Massa**	**%**	**Massa**	**%**
Urea	118,211	0,36	118,170	0,95	0,041	0,0002
Formalin	176,134	0,53	176,073	1,41	0,061	0,0003
Metanol	2.396,169	7,20	2.395,344	19,21	0,825	0,0040
Air	9.383,361	28,21	9.380,129	75,22	3,232	0,0155
$C_2H_6N_2O_2$	173,770	0,52	173,710	1,39	0,060	0,0003
$C_3H_8N_2O_3$	227,060	0,68	226,981	1,82	0,078	0,0004
$C_6H_{14}N_4O_4$	20.792,994	62,50	0	0	20.792,994	99,9793
Sub Total	33.267,700	100	12.470,409	100	20.797,291	100
Total	**33.267,700**		**33.267,700**			

LAMPIRAN B. NERACA ENERGI

- Persamaan yang digunakan untuk menghitung nilai panas (Q)
  - $Q = m\,Cp\,\Delta T$ (Himmelblau, Pers.23.12, Hal. 693)
  - Menggunakan data Cp yang diperoleh dari Perry's tabel 2-394 *Atomic Group Contribution to estimate Liquid Heat Capasity at 293,15K* dan Tabel 2-393 *Atomic Group Contribution to estimate solid Heat Capasity at 293,15K* (halaman 402)
- Persamaan yang digunakan untuk menghitung panas reaksi (Qr)
  - $Qr = -\Delta H_R$ (Himmelblau, Pers.25.1, Hal. 770)
  - $-\Delta H_R = \Delta H_R^o + (\Delta H_{produk} - \Delta H_{reaktan})$
  - $-\Delta H_R^\circ = \Delta H_{f\,produk}^o - \Delta H_{f\,reaktan}^o$
  - $\Delta H_{produk} = \sum(m.Cp.\Delta T)_{produk}$
  - $\Delta H_{reaktan} = \sum(m.Cp.\Delta T)_{reaktan}$

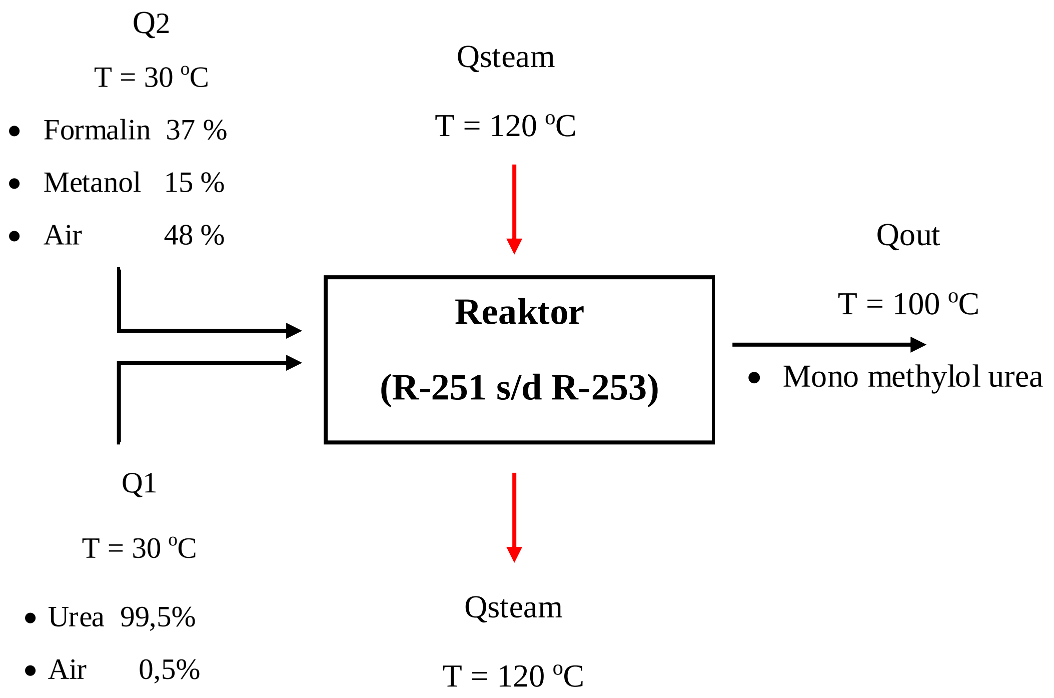
  - Nilai data ΔH_f^o diperoleh dari *Perry's*, halaman 397 , Tabel 2-388 *Atomic Group Contribution to Estimate* $\Delta H_{f\,298,15}^o$
- Nilai kapasitas dan panas pembentukan dapat dilihat pada tabel LB.1 :

Tabel LB.1 Nilai Kapasitas Panas (Cp) dan Panas Pembentukan ΔH_f^o

Komponen	Rumus Kimia	Delta Hf (KJ/kmol)	Cp (KJ/kmol.K)
Urea	$CO(NH_2)_2$	-108,97	92,03
Formalin	CH_2O	-64,93	82,25
Mono methylol urea	$C_2H_6O_2N_2$	-262,16	228,7
Di methylol Urea	$C_3H_8O_3N_2$	-415,35	214,05
Urea Formaldehid	$C_6H_{14}O_5N_4$	-867,76	313,24
Metanol	CH_3OH	-216,2	81,59
Air	H_2O	63,93	49,79

1. Reaktor (R-251 s/d R-253)

1.1. Reaksi 1



Kondisi Operasi :

- Temperatur = 100 °C
- Tekanan = 1 atm
- Tin Q1 dan Q2 = 30 °C

❖ **Input**

- Q1
  - Tin = 30 °C = 303,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.2 Energi Q1 Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Urea	60	5.910,5509	98,5092	92,03	5	45.328,999
Air	18	29,7013	1,6501	49,79	5	410,7849
Total						**45.739,785**

- **Q2**
  - Tin = 30 ^{o}C = 303,15 K
  - Tref = 25 ^{o}C = 298,15 K

Tabel LB.3 Energi Q2 Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Formalin	30	5.910,55	197,02	82,25	5	81.023,80
Metanol	32	2.396,17	74,88	81,59	5	30.547,41
Air	18	7.667,74	425,99	49,79	5	106.049,13
Total						**217.620,34**

❖ Output

- Qout
  - Tin = 100 ^{o}C = 373,15 K
  - Tref = 25 ^{o}C = 298,15 K

Tabel LB.4 Energi Qout Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT (K)	ΔH1 (kJ/jam)
Formalin	30	3.014,3809	100,4794	82,25	75	619.832,081
Metanol	32	2.396,1693	74,8803	81,59	75	458.211,212
Air	18	7.697,4429	427,6357	49,79	75	1.596.898,7
Urea	60	118,2110	1,9702	92,03	75	13.598,699
Mono methylol urea	90	8.688,5098	96,5390	228,7	75	1.655.885,2
Total						**4.344.425.8**

➢ Panas Reaksi standar (T = 298,15 K)

Konversi rx : 98%

Reaksi 1:

	$CO(NH_2)_2$	+	CH_2O	→	NH2-CO-HN-CH2OH
Mula2 :	98,5091		197,0184		
Reaksi :	96,5390		96,5390		96,5390
Sisa :	1,9707		100,4794		96,5390

Tabel LB.5 Data Nilai ΔHf° Reaktan dan Produk

Komponen	n(kmol/jam)	ΔHf (kJ/jam)	n. ΔHf	Total(n. ΔHf)
Reaktan				
Formalin	96,5390	-64,9300	-6.268,2771	-16.788,1316
Urea	96,5390	-108,9700	-10.519,8545	
Produk				
Mono methylol urea	96,5390	-262,1600	-25.308,6636	-25.308,6636

Δ Hr° = [n . ∑ΔHf° produk] - [n . ∑ ΔHf° reaktan]

= -25.308,6636 - (-16.788,1316)

= -8.520,5319 kJ/jam

- Panas Reaksi Toperasi (T=373,15K)
  - Tin = 100 °C = 373,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.6 Energi Qreaktan Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Formalin	30	2.896,17	96,54	82,25	75	595.524,94
Urea	60	5.792,34	96,54	92,03	75	666.336,29
Total						**1.261.861,2**

Tabel LB.7 Energi Qproduk Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Mono methylol urea	90	8.688,5098	96,54	228,7	75	1.655.885,2
Total						**1.655.885,2**

$$\Delta H_r = \Delta H_r^{\ 0} + [\sum \Delta H_{PRODUK} - \sum \Delta H_{REAKTAN}]$$

ΔHr(Top = 100°C) = -8.520,5319 kJ/jam + (1.655.885,2-1.261.861,2) kJ/jam

= 385.503,3859 kJ/jam

Qr = -ΔHr

Qr = -385.503,3859 kJ/jam

- **Beban Pemanas Reaktor**

  ΔQ(pemanas) = Qout – (Q1 + Q2 + Qr)

  = 4.344.425.8 – (45.739,785 + 217.620,34 + (-385.503,3859))

  = 4.466.569,0829 kJ/jam

- ***Steam***

  Media pemanas adalah *saturated steam* pada temperatur 120 °C (smith van ness, Tabel F.1 *Saturated steam*, hal : 683

  Sehingga :

  Hl = 503,7 kJ/kg

  Hv = 706 kJ/kg

  λ = Hv – Hl

  = 202,3 kJ/kg

- Banyaknya Steam yang dibutuhkan

  Q(pemanas) = Massa steam x λ steam

  Massa steam $= \frac{4.466.569{,}0829 \text{ kJ/jam}}{202{,}3 \text{ kJ/kg}}$

  = 22.078,9376 kg/jam

  - Qs in = massa steam x Hv

    = 15.587.729,9682 kJ/jam

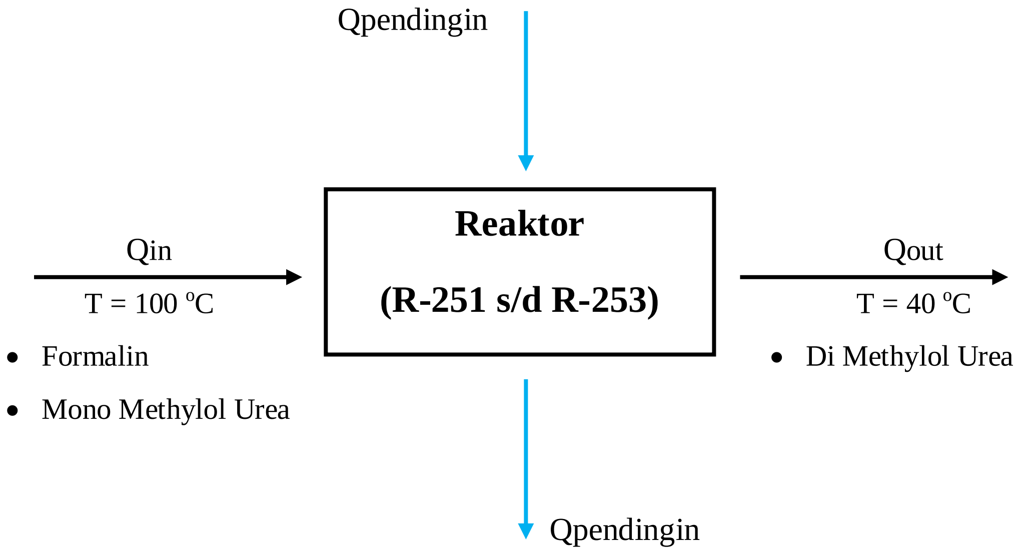
  - Qs out = massa steam x Hl

    = 11.121.160,8852 kJ/jam

Tabel LB.8 Neraca Energi Reaktor (R-251 s/d R-253)(Reaksi 1)

Komponen	Masuk (kJ/jam)	Keluar (kJ/jam)
Q1	45.739,785	
Q2	217.620,34	
Qout		4.344.425.8241
Qr		385.503,3859
Qpemanas	4.466.569,0829	
Total	**4.729.929,21**	**4.729.929,21**

1.2. Reaksi 2



Kondisi Operasi :

- Temperatur = 40 °C
- Tekanan = 1 atm
- Tin Qin = 100 °C

❖ **Input**

- Qin
  - Tin = 100 °C = 373,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.9 Energi Qin Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔHin (kJ/jam)
Formalin	30	3.014,3809	100,4794	82,25	75	619.832,08
Metanol	32	2.396,1693	74,8803	81,59	75	458.211,21
Urea	60	118,2110	1,9702	92,03	75	13.598,69
Air	18	7.697,4429	427,6357	49,79	75	1.596.898,7
Mono methylol urea	90	8.688,5098	96,5390	228,70	75	1.655.885,2
Total						**4.344.425,82**

❖ Output

- Qout
  - Tout = 40 °C = 313,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.10 Energi Qout Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT (K)	ΔH1 (kJ/jam)
Formalin	30	176,1344	5,8711	82,25	15	7.243,5278
Metanol	32	2.396,1693	74,8803	81,59	15	91.642,2425
Air	18	7.697,5529	427,6357	49,79	15	319.379,736
Urea	60	118,2110	1,9702	92,03	15	2.719,7400
Mono methylol urea	90	173,7702	1,9308	228,70	15	6.623,5406
Di methylol Urea	120	11.352,986	94,6082	214,05	15	303.763,334
Total						**731.372,121**

- Panas Reaksi standar (T = 298,15 K)

Konversi rx : 98%

Reaksi 2 :

NH_2-CO-HN-CH_2OH + CH_2O → CH2OH-HN-CO-HN-CH2OH

Mula2 :	96,5390	100,4794	
Reaksi :	94,6082	94,6082	94,6082
Sisa :	1,9308	5,8711	94,6082

Tabel LB.11 Data Nilai ΔHf° Reaktan dan Produk

Komponen	n(kmol/jam)	ΔHf (kJ/jam)	n. ΔHf	Total(n. ΔHf)
Reaktan				
Formalin	94,6082	-64,9300	-6.142,9116	-30.945,4018
Mono methylol urea	94,6082	-262,1600	-24.802,4903	
Produk				
Di methylol urea	94,6082	-415,35	-39.295,5231	-39.295,5231

ΔHr^o = [n . ∑ΔHf° produk] - [n . ∑ ΔHf° reaktan]

= -39.295,5231- (-30.945,4018)

= -8.350,1213 kJ/jam

- Panas Reaksi Toperasi (T=313,15K)
  - Tin = 40 °C = 313,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.12 Energi Qreaktan Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Formalin	30	2.838,2465	94,6082	82,25	15	116.722,88
Mono methylol urea	90	8.514,7396	94,6082	228.70	15	324.553,49
Total						**441.276,378**

Tabel LB.13 Energi Qproduk Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Di methylol urea	120	11.352,986	94,6082	214,05	15	303.763,334
Total						**303.763,334**

$$\Delta H_r = \Delta H_r^{\ 0} + [\sum \Delta H_{PRODUK} - \sum \Delta H_{REAKTAN}]$$

ΔHr(Top = 40°C) = -8.350,1213 kJ/jam + (303.763,334 - 441.276,378) kJ/jam
= -145.863,1653 kJ/jam

Qr = -ΔHr

Qr = 145.863,1653 kJ/jam

- **Beban Panas Reaktor**

  ΔQ(pendingin) = Qout – (Qin + Qr)

  = 731.372,121 – (4.344.425,82 + 145.863,1653) kJ/jam

  = -3.758.916,8686 kJ/jam

- **Air Pendingin**

❖ Banyaknya air pendingin yang dibutuhkan

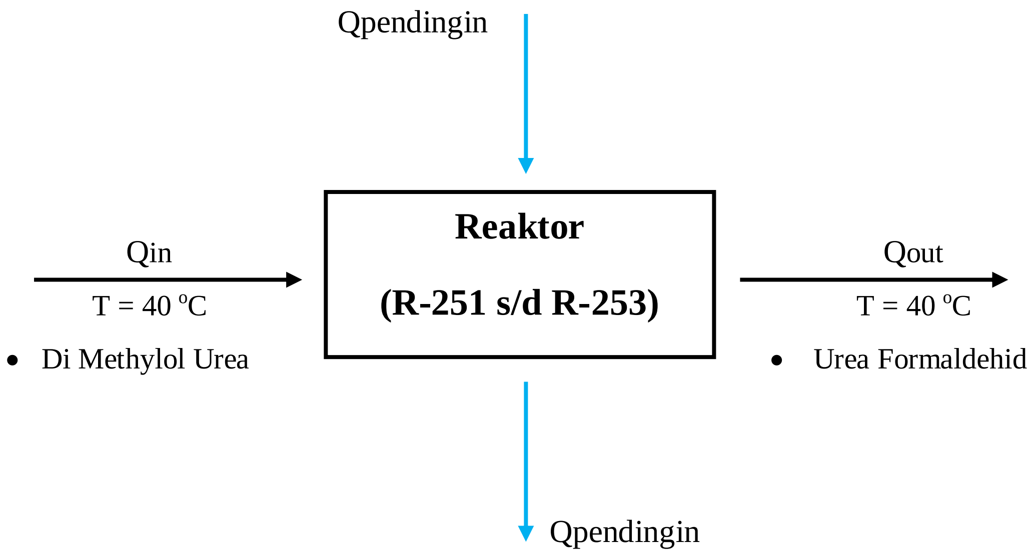
Q(pendingin) $= \frac{BM\ AIR}{Massa\ Air\ pendingin}$ x Cp Air

Massa air pendingin = 4.194,1899 kg/jam

Tabel LB.14 Neraca Energi Reaktor (R-251 s/d R-253)(Reaksi 2)

Komponen	Masuk (kJ/jam)	Keluar (kJ/jam)
Qin	4.344.425,82	
Qout		731.372,121
Qr	145.863,1653	
Qpendingin	-3.758.916,8686	
Total	**731.372,121**	**731.372,121**

1.3. Reaksi 3



Kondisi Operasi :

- Temperatur = 40 °C
- Tekanan = 1 atm
- Tin Qin = 40 °C

❖ **Input**

- Qin
  - Tin = 40 °C = 313,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.15 Energi Qin Reaktor (R-251 s/d R-253)

Komponen	**BM**	**Massa (kg/jam)**	**Mol (kmol/jam)**	**Cp (kJ/kmol.K)**	**ΔT**	**ΔHin (kJ/jam)**
Formalin	30	176,1344	5,8711	82,25	15	7.243,5278
Metanol	32	2.396,1692	74,8803	81,59	15	91.642,2425
Air	18	7.697,4429	427,6357	49,79	15	319.379,7357
Urea	60	118,2110	1,9702	92,03	15	2.719,74
Mono methylol urea	90	173,7702	1,9308	228,70	15	6.623,5406
Di methylol urea	120	11.352,9861	94,6082	214,05	15	303.763,3342
Di methylol urea	120	11.352,9861	94,6082	214,05	15	303.763,3342
Total						**1.035.135,4549**

❖ Output

- Q3
  - T3 = 40 °C = 313,15 K
  - Tref = 25 °C = 298,15 K

Tabel LB.16 Energi Qout Reaktor (R-251 s/d R-253)

Komponen	**BM**	**Massa (kg/jam)**	**Mol (kmol/jam)**	**Cp (kJ/kmol.K)**	**ΔT (K)**	**ΔH1 (kJ/jam)**
Formalin	30	176,1344	5,8711	82,25	15	7.243,5278
Metanol	32	2.396,1693	74,8803	81,59	15	91.642,2425

Air	18	9.383,3614	521,2979	49,79	15	389.331,301
Urea	60	118,2110	1,9702	92,03	15	2.719,7400
Mono methylol urea	90	173,770	1,9308	228,70	15	6.623,5406
Di methylol Urea	120	227,0597	1,8922	214,05	15	6.075,2667
Urea Formaldehid	222	20.792,99	93,6621	313,24	15	440.080,91
Total						**943.716,528**

- Panas Reaksi standar (T = 298,15 K)

Konversi rx : 99%

Reaksi 3 :

Dimethylol urea + Dimethylol urea $\xrightarrow{-H_20 \text{ kondensas}}$ Urea Formaldehid + H_2O

Mula2 :	94,6082	94,6082		
Reaksi :	93,6621	93,6621	93,6621	93,6621
Sisa :	0,9461	0,9461	93,6621	93,6621

Tabel LB.17 Data Nilai ΔHf° Reaktan dan Produk

Komponen	**n(kmol/jam)**	**ΔHf (kJ/jam)**	**n. ΔHf**	**Total(n. ΔHf)**
Reaktan				
Di methylol urea	93,6621	-415,35	-38.902,5679	-77.805,1358
Di methylol urea	93,6621	-415,35	-38.902,5679	
Produk				
Urea Formaldehid	93,6621	-867,76	-81.276,2545	-87.264,0748
Air	93,6621	-63,93	-5.987,8203	

Δ Hr° = [n . ∑ΔHf° produk] - [n . ∑ ΔHf° reaktan]

= -87.264,0748- (-77.805,1358)

= -9.458,9390 kJ/jam

- Panas Reaksi Toperasi (T=313,15K)
  - Tin = 40 ^{o}C = 313,15 K
  - Tref = 25 ^{o}C = 298,15 K

Tabel LB.18 Energi Qreaktan Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Di methylol urea	120	11.239,456	93,6621	214,05	15	300.725,700
Di methylol urea	120	11.239,456	93,6621	214,05	15	300.725,700
Total						**601.451,402**

Tabel LB.19 Energi Qproduk Reaktor (R-251 s/d R-253)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT	ΔH1 (kJ/jam)
Urea Formaldehid	222	20.792,994	93,6621	313,24	15	440.080,909
Air	18	1.685,9184	93,6621	49,79	15	69.951,5657
Total						**510.032,474**

$$\Delta H_r = \Delta H_r^{\ 0} + [\sum \Delta H_{PRODUK} - \sum \Delta H_{REAKTAN}]$$

ΔHr(Top = 40^{o}C) = -9.458,9390 kJ/jam + (510.032,474 - 601.451,402) kJ/jam

= -100.877,8662 kJ/jam

Qr = -ΔHr

Qr = 100.877,8662 kJ/jam

- **Beban Panas Reaktor**

  ΔQ(pendingin) = Q3 – (Qin + Qr)

  = 943.716,528 – (1.035.135,4549 + 100.877,8662) kJ/jam

  = -192.296,7933 kJ/jam

- **Air Pendingin**
- Banyaknya air pendingin yang dibutuhkan

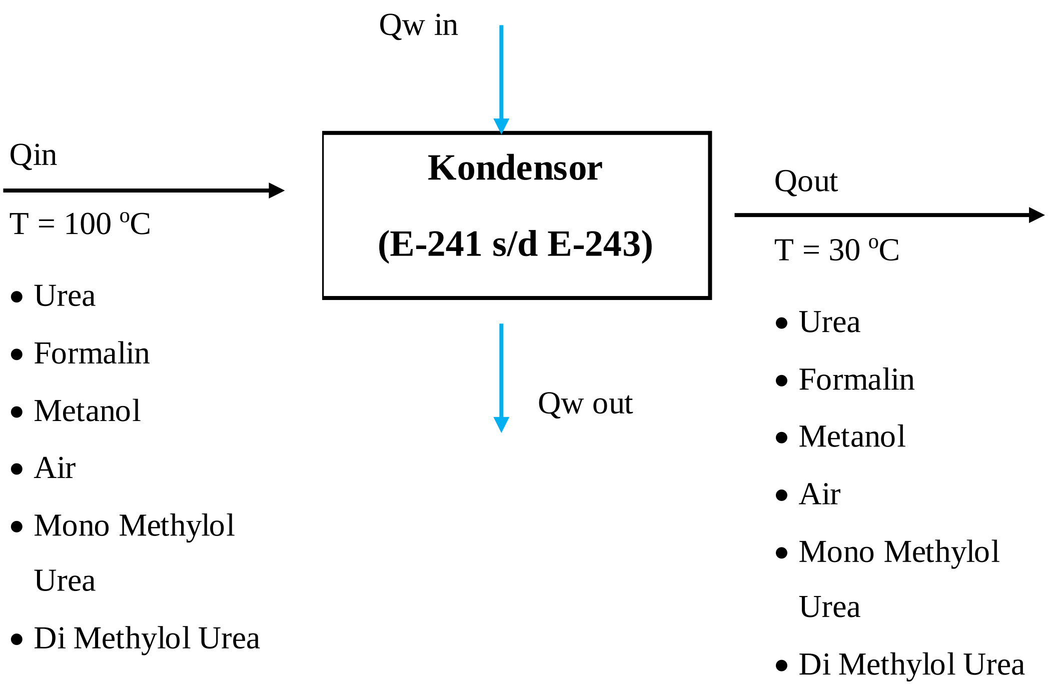
Q(pendingin) $= \dfrac{BM\ AIR}{Massa\ Air\ pendingin}$ x Cp Air

Massa air pendingin = 214,5643 kg/jam

Tabel LB.20 Neraca Energi Reaktor (R-251 s/d R-253)(Reaksi 2)

Komponen	Masuk (kJ/jam)	Keluar (kJ/jam)
Qin	1.035.135,4549	
Qout		943.716,528
Qr	100.877,8662	
Qpendingin	-192.296,7933	
Total	**943.716,528**	**943.716,528**

2. Kondensor (E-241 s/d E-243)



Kondisi Operasi :

- Temperatur masuk : 100 ^oC
- Tekanan : 1 atm
- Tout : 30 ^oC

➢ **Input**

- Qin
  - Tin = 100 ^oC = 373,15 K
  - Tref = 25 ^oC = 298,15 K

Tabel LB.21 Energi Qin Kondensor (E-241 s/d E-243)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT (K)	ΔH1 (kJ/jam)
Urea	60	118,2110	1,9702	92,03	75	13.598,6999
Formalin	30	176,1344	5,8711	82,25	75	36.217,6392
Metanol	32	2.396,1693	74,8803	81,59	75	458.211,212
Air	18	9.383,3614	521,2979	49,79	75	1.946.656,5
Mono methylol urea	90	173,7702	1,9308	228,70	75	33.117,7031
Di methylol Urea	120	227,0597	1,8922	214,05	75	30.376,3334
Urea Formaldehid	222	20.792,994	93,6621	313,24	75	2.200.404,5
Total						**4.718.582,6**

- Qout
  - Tout = 30 ^oC = 303,15 K
  - Tref = 25 ^oC = 298,15 K

Tabel LB.22 Energi Qout Kondensor (E-241 s/d E-243)

Komponen	BM	Massa (kg/jam)	Mol (kmol/jam)	Cp (kJ/kmol.K)	ΔT (K)	ΔH1 (kJ/jam)
Urea	60	118,2110	1,9702	92,03	5	906,5800
Formalin	30	176,1344	5,8711	82,25	5	2.414,5093
Metanol	32	2.396,1693	74,8803	81,59	5	30.547,4142

Air	18	9.383,3614	521,2979	49,79	5	129.777,100
Mono methylol urea	90	173,7702	1,9308	228,70	5	2.207,8469
Di methylol Urea	120	227,0597	1,8922	214,05	5	2.025,0889
Urea Formaldehid	222	20.792,994	93,6621	313,24	5	146.693,636
Total						**314.572,175**

- Beban Kondensor

  ΔQ(pendingin) = Qout – Qin

  = 314.572,175 - 4.718.582,6390

  = -4.404.010,4630 kJ/jam

- Jumlah air pendingin yang dibutuhkan :

  Massa air pendingin = ΔQ / (Cp x ΔT)

  = 17.690,3413 kg/jam

- QW in = massa air pendingin x Cp air

  = 880.802,0926 kJ/jam

- QW out = (Qin + QW in) – (Qout)

  = 5.284.812,5556 kJ/jam

Tabel LB.20 Neraca Energi Reaktor (R-251 s/d R-253)(Reaksi 2)

Komponen	Masuk (kJ/jam)	Keluar (kJ/jam)
Qin	4.718.582,6390	
QW in	880.802,0926	
Qout		314.572,175
QW out		5.284.812,5556
Total	**5.599.384,7316**	**5.599.384,7316**

LAMPIRAN C. SPESIFIKASI PERALATAN

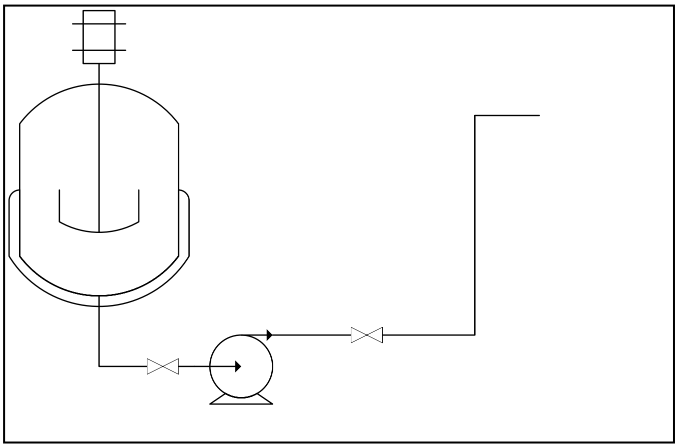
A. Spesifikasi Peralatan Utama

1. Pompa (J-121)

Fungsi : Mengalirkkan Formalin dari Tangki Penyimpanan ke Reaktor

Tipe : *Centrifugal pump*

Gambar :



Gambar C-2 Aliran pompa (J-221)

Data :

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

- Laju alir massa, m : 15.974,4618 kg/jam = 35.223,6882 lb/jam
- Densitas , ρ : 898,9100 kg/m^3 = 56,1341 lb/ft^3
- Viskositas , µ : 0,0012777 cP = 0,0000009 lb/ft.s
- Tinggi pompa terhadap cairan masuk, Z_a : 0,5 m = 1,64 ft
- Tinggi pompa terhadap cairan keluar, Z_b : 4,5 m = 14,7638 ft
- Panjang pipa hisap, L_s : 2 m = 6,5617 ft
- Panjang pipa buang, L_d : 5 m = 16,4042 ft
- Faktor keamanan 10% (Peter's, Tabel 6)

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TABLE 6
Factors in equipment scale-up and design

Type of equipment	Is pilot plant usually necessary?	Major variables for operational design (other than flow rate)	Major variables characterizing size or capacity	Maximum scale-up ratio based on indicated characterizing variable	Approximate recommended safety or over-design factor, %
Agitated batch crystallizers	Yes	Solubility-temperature relationship	Flow rate Heat transfer area	>100:1	20
Batch reactors	Yes	Reaction rate Equilibrium state	Volume Residence time	>100:1	20
Centrifugal pumps	No	Discharge head	Flow rate Power input Impeller diameter	>100:1 >100:1 10:1	10

Laju alir volumetrik, Q_v

$$Q_p = \frac{m}{0,9}$$

$$= \frac{38.746,0571 \text{ lb/jam}}{0,9}$$

= 38.746,0571 lb/jam =10,7628 lb/s

$$Q_v = \frac{Qp}{\rho}$$

$$= \frac{10,7628 \text{ lb/s}}{56,1341 \text{ lb/ft}^3}$$

= 0,1917 ft^3/s

Diameter optimum, D_{opt}

Asumsi aliran turbulen

$$D_{opt} = 3,9 * Qv^{0,45} * \rho^{0,13}$$ (Peter, Pers 14.15)

making design estimates:

For turbulent flow (N_{Re} > 2100) in steel pipes

$$D_{i,opt} = 3.9 q_f^{0.45} \rho^{0.13} \quad (15)$$

For viscous flow (N_{Re} < 2100) in steel pipes

$$D_{i,opt} = 3.0 q_f^{0.36} \mu_c^{0.18} \quad (16)$$

Peter, Hal 496

$$D_{opt} = 3,9 \times 0,1917^{0,45} \times 56,1341^{0,13}$$

= 3,1310 in

Berdasarkan Tabel 11 Kern, diperoleh pipa baja dengan ukuran sebagai berikut :

Nominal pipe size, in.	Outside diameter, in.	Schedule no.	Wall thickness, in.	Inside diameter, in.	Cross-sectional area of metal, in.^{2}	Inside sectional area, ft^2	Circumference, ft or surface, ft^2/ft of length		Capacity at 1 ft/s velocity		Pipe weight lb/ft
							Outside	Inside	U.S. gal/min	Water, lb/h	
2	2.375	40	0.154	2.067	1.075	0.02330	0.622	0.541	10.45	5,225	3.65
		80	0.218	1.939	1.477	0.02050	0.622	0.508	9.20	4,600	5.02
$2\frac{1}{2}$	2.875	40	0.203	2,469	1.704	0.03322	0.753	0.647	14.92	7,460	5.79
		80	0.276	2.323	2.254	0.02942	0.753	0.608	13.20	6,600	7.66
3	3.500	40	0.216	3.068	2.228	0.05130	0.916	0.803	23.00	11,500	7.58
		80	0.300	2.900	3.016	0.04587	0.916	0.759	20.55	10,275	10.25
$3\frac{1}{2}$	4.000	40	0.226	3.548	2.680	0.06870	1.047	0.929	30.80	15,400	9.11
		80	0.318	3.364	3.678	0.06170	1.047	0.881	27.70	13,850	12.51
4	4.500	40	0.237	4.026	3.17	0.08840	1.178	1.054	39.6	19,800	10.79
		80	0.337	3.826	4.41	0.07986	1.178	1.002	35.8	17,900	14.98
5	5.563	40	0.258	5.047	4.30	0.1390	1.456	1.321	62.3	31,150	14.62
		80	0.375	4.813	6.11	0.1263	1.456	1.260	57.7	28,850	20.78
6	6.625	40	0.280	6.065	5.58	0.2006	1.734	1.588	90.0	45,000	18.97
		80	0.432	5.761	8.40	0.1810	1.734	1.508	81.1	40,550	28.57
8	8.625	40	0.322	7.981	8.396	0.3474	2.258	2.089	155.7	77,850	28.55
		80	0.500	7.625	12.76	0.3171	2.258	1.996	142.3	71,150	43.39
10	10.75	40	0.365	10.020	11.91	0.5475	2.814	2.620	246.0	123,000	40.48
		80	0.594	9.562	18.95	0.4987	2.814	2.503	223.4	111,700	64.40
12	12.75	40	0.406	11.938	15.74	0.7773	3.338	3.13	349.0	174,500	53.56
		80	0.688	11.374	26.07	0.7056	3.338	2.98	316.7	158,350	88.57

	Suction (a)	Discharge (b)
IPS	4 in Sch 80	
ID	3,8260 in = 0,3188 ft	3,8260 in = 0,3188 ft
OD	4,5000 in = 0,3750 ft	4,5000 in = 0,3750 ft
a”	0,1390 ft^2	

Kecepatan aliran, V

Va = Vb, karena ukuran pipa hisap dan pipa buang sama

$$V = \frac{Qv}{a''}$$

$$= \frac{0,1917 \text{ ft}^3/\text{s}}{0,0799 \text{ ft}^2}$$

$$= 2,4009 \text{ ft/s}$$

$$\frac{V^2}{2gc} = \frac{5,764 \text{ ft/s}}{2 \text{ x} 32,17 \text{ lbmft/s}^2 \text{ lbf}}$$

$$= 0,0896 \text{ ft-lb}_f/\text{lb}$$

Bilangan Reynolds, N_{Re}

$$N_{Re} = \frac{\rho \text{ x V x D}}{\mu}$$

SIGNIFICANCE OF DIMENSIONLESS GROUPS.[23] The three dimensionless groups in Eq. (9.14) may be given simple interpretations. Consider the group $nD_a^2\rho/\mu$. Since the impeller tip speed u_2 equals $\pi D_a n$,

$$N_{Re} = \frac{nD_a^2\rho}{\mu} = \frac{(nD_a)D_a\rho}{\mu} \propto \frac{u_2 D_a \rho}{\mu} \qquad (9.17)$$

and this group is proportional to a Reynolds number calculated from the diameter and peripheral speed of the impeller. This is the reason for the name of the group.

Mc,Cabe Hal 249

$$N_{Re} = \frac{56{,}1341\ \text{lb/ft}^3 \times 2{,}4009\ \text{ft/s} \times 0{,}3188\ \text{ft}}{0{,}000001\ \text{lb/ft.s}}$$

= 500.047.193,53

Rugi Gesek

- **Pipa hisap (*suction*)**

- **Rugi gesek akibat gesekan dengan kulit pipa**

$$h_{fsa} = f\,\frac{\Delta L}{r_H}\,\frac{V^2}{2gc} \qquad \text{(Mc Cabe, Pers 5.56)}$$

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where D_i and D_o are the inside and outside diameters of the annulus, respectively. The equivalent diameter of an annulus is therefore the difference of the diameters. Also, the equivalent diameter of a square duct with a width of side b is $4(b^2/4b) = b$.

The hydraulic radius is a useful parameter for generalizing fluid-flow phenomena in turbulent flow. Equation (5.7) can be so generalized by substituting $4r_H$ for D or $2r_H$ for r_w:

$$h_{fs} = \frac{\tau_w}{\rho r_H}\Delta L = \frac{\Delta p_s}{\rho} = f\,\frac{\Delta L}{r_H}\,\frac{\bar{V}^2}{2g_c} \qquad (5.56)$$

$$N_{Re} = \frac{4r_H \bar{V}\rho}{\mu} \qquad (5.57)$$

Mc.Cabe

$$r_H = \frac{ID}{10} \qquad \text{McCabe, Hal 103}$$

Thus, for the special case of a circular tube, the hydraulic radius is

$$r_H = \frac{\pi D^2/4}{\pi D} = \frac{D}{4}$$

Mc.Cabe Hal 103

$$r_H = \frac{0{,}3188\ \text{ft}}{10} = 0{,}0319\ \text{ft}$$

Nre = 500.047.193,53

Material pipa yang digunakan adalah *wrought iron steel* :

k = 0,00015 ft　　Mc.Cabe Fig 5.9

k/D = 0,0005

f = 0,0043 Mc.Cabe Fig. 5.9

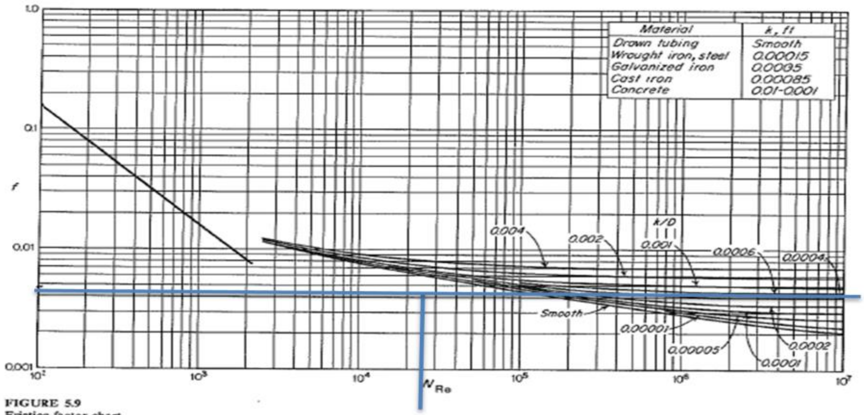


FIGURE 5.9
Friction-factor chart.

$$h_{fsa} = \frac{0{,}0043 \text{ x } 6{,}5617 \text{ ft x } 0{,}0896 \text{ ft - lb}_f\text{/lb}}{0{,}0319\ ft}$$

$= 0{,}079$ ft-lb$_f$/lb

- **Rugi gesek akibat *fitting dan valve* (hff)**

$$h_{ffa} = Kf \frac{V^2}{2gc}$$ Mc.Cabe Pers 5.67

EFFECT OF FITTINGS AND VALVES. Fittings and valves disturb the normal flow lines and cause friction. In short lines with many fittings, the friction loss from the fittings may be greater than that from the straight pipe. The friction loss h_{ff} from fittings is found from an equation similar to Eqs. (5.59) and (5.65):

$$h_{ff} = K_f \frac{\bar{V}_a^2}{2g_c} \quad (5.67)$$

Mc.Cabe Hal 107

where K_f = loss factor for fitting
$\bar{V}_a$ = average velocity in pipe leading to fitting

Kf *elbow* = 0,9 Mc.Cabe, Tabel 5.1

Kf (globe valve) = 10

TABLE 5.1
Loss coefficients for standard threaded pipe fittings†

Fitting	K_f
Globe valve, wide open	10.0
Angle valve, wide open	5.0
Gate valve	
Wide open	0.2
Half open	5.6
Return bend	2.2
Tee	1.8
Elbow	
90°	0.9
45°	0.4

† From J. K. Vennard, in V. L. Streeter (ed.), *Handbook of Fluid Dynamics*, McGraw-Hill Book Company, New York, 1961, p. 3–23.

h_{ffa} = 10,9 x 0,1582 ft - lb_f /lb

= 1,7242 ft.lbf/lb

- **Rugi Gesek Karena Pengecilan (Kontraksi) dari Reaktor ke pipa**

h_{fca} $= Kc\dfrac{V^2}{2gc}$ (Mc. Cabe, Pers. 5.64 Hal. 106)

The friction loss from sudden contraction is proportional to the velocity head in the smaller conduit and can be calculated by the equation

$$h_{fc} = K_c \frac{\bar{V}_b^2}{2g_c} \qquad (5.65)$$

Mc.Cabe Hal 106

Kc $= 0,4\left(1-\dfrac{Sb}{Sa}\right)$

Sb = 5,5630 in = 0,46339 ft (diameter pipa)

Sa = 3,9017m = 12,7978 ft (diameter Reaktor R-2041)

Kc $= 0,4\left(1-\dfrac{0,21\ ft}{9,53\ ft}\right)$

= 0,3855

H_{fca} = 0,3855 x 0,1582 ft.lb_f/lb

= 0,0609 ft.lb_f/lb

hf suction total = hfs + hff + hfc

= (0,1061+ 1,7242 +0,0609) ft.lb_f/lb

= 1,8913 ft.lb_f/lb

- **Pipa buang (*discharge*)**

- **Rugi gesek akibat gesekan dengan kulit pipa**

H_{fsb} $= f\dfrac{\Delta L}{r_H}\dfrac{V^2}{2gc}$ (Mc Cabe, Pers 5.56)

r_H $= \dfrac{ID}{4}$ (McCabe, Hal 103)

r_H $= \dfrac{0,4206\ \text{ft}}{4} = 0,1051$ ft

Nre = 24.507,7424

Material pipa yang digunakan adalah *Commersial steel pipe* :

k $= 0{,}00015$ ft (Mc.Cabe Fig 5.9)

k/D $= 0{,}0004$

f $= 0{,}0043$ (Mc.Cabe Fig. 5.9

$$h_{fsb} = \frac{0{,}0043 \text{ x } 22{,}9659 \text{ ft x } 0{,}1582 \text{ft - lb}_f/\text{lb}}{0{,}1051\,ft}$$

$= 0{,}1486$ ft.lb$_f$/lb

- **Rugi gesek akibat *fitting*(hff)**

$$H_{ffb} = Kf\,\frac{V^2}{2gc}$$ Mc.Cabe Pers 5.67

Kf elbow $= 0{,}9 \text{ x } 2 = 1{,}8$ Mc.Cabe, Tabel 5.1

Kf Globe Valve $= 10 \text{ x } 1 = 10$

Kf $= 11{,}8$

H_{ffb} $= 11{,}8 \text{ x } 0{,}1582$ ft.lb$_f$/lb

$= 1{,}8666$ ft.lb$_f$/lb

- **Rugi Gesek Pembesaran (Ekspansi) dari Pipa ke Tangki Reaktor**

$$h_{feb} = Ke\frac{V^2}{2gc}$$

$$K_e = \left(1 - \frac{Sa}{Sb}\right)^2$$ Mc.Cabe Pers 5.64

$$K_e = \left(1 - \frac{S_a}{S_b}\right)^2 \qquad (5.64)$$

Sa = 5 in = 0,46339 ft (diameter pipa)

Sb = 2,44 m =8 ft (diameter RVF)

$$Ke = \left(1 - \frac{0{,}46339\ ft}{8\ ft}\right)^2 = 0{,}8875$$

h_{feb} $= 0{,}8875 \text{ x } 0{,}1582$ ft.lb$_f$/lb

$= 0{,}1403$ft.lb$_f$/lb

hf *discharge* total = hfs + hff + hfe

z= (0,1486+ 1,8666 +0,1403) ft.lb$_f$/lb

$= 2,1555 \text{ ft.lb}_f/\text{lb}$

Sehingga, rugi gesek total (hf_{total}) :

hf_{total} $= hf \text{ suction} + hf \text{ dischage}$

$= 1,8913 + 2,1555 \text{ ft.lb}_f/\text{lb}$

$= 4,0468 \text{ ft.lb}_f/\text{lb}$

Daya Pompa (BHP)

Daya pompa dapat dihitung dengan menggunakan Persamaan Bernoulli (McCabe, Pers. 4.32):

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

Atau

$$\eta W_p = \left(\frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c}\right) - \left(\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c}\right) + h_f$$

The mechanical energy delivered to the fluid is, then, ηW_p, where $\eta < 1$. Equation (4.29) corrected for pump work is

$$\frac{p_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a \bar{V}_a^2}{2g_c} + \eta W_p = \frac{p_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b \bar{V}_b^2}{2g_c} + h_f \qquad (4.32)$$

Equation (4.32) is a final working equation for problems on the flow of incompressible fluids. Mc.Cabe

Dimana

P_a $= P_b$

V_a $= V_b$

ρ_a $= \rho_b$

g/g_c $= 1$

α_a $= \alpha_b$

Q $= 0,1917 \text{ ft}^3/\text{s} = 86,061483 \text{ gal/min}$

η $= 65\ \%$ (Peters, Fig. 14.36)

FIGURE 1436
Characteristic curves for a typical centrifugal pump showing effect of viscosity.

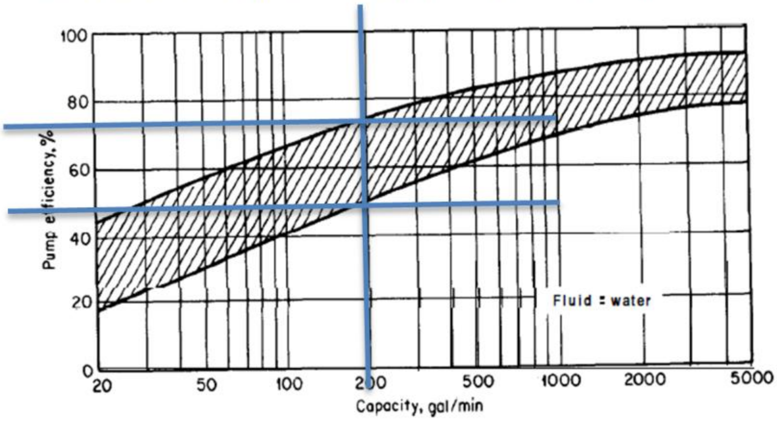


FIGURE 1437
Efficiencies of centrifugal pumps.

Sehingga persamaan di atas dapat disederhanakan menjadi :

$$\eta W_p = (Zb - Za) + hf$$

Wp $= \dfrac{(14{,}7638 - 1{,}6404)\ \text{ft} + 2{,}1922\ \text{ft.lb}_f/\text{lb}}{62\%}$

$= 23{,}5625\ \text{ft.lb}_f/\text{lb}$

BHP $= \dfrac{\text{Wp x m}}{550}$

$= \dfrac{23{,}5625\ \text{ft.lbf/lb} \ \text{x}\ 10{,}7628\ \text{lb/s}}{550}$

$= 0{,}4611$ HP

Daya motor (MHP)

MPH $= \dfrac{\text{BHP}}{\eta}$

η = 80 % (Peters, Fig 14.38)

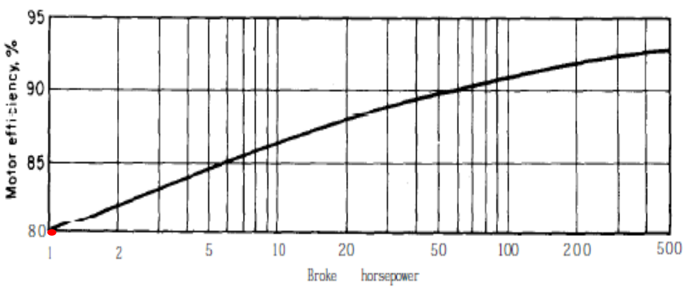


FIGURE 1438
Efficiencies of three-phase motors.

$$\text{MPH} = \frac{0{,}4611\ \text{HP}}{0{,}8}$$

= 0,5764 HP

Tabel C.2 Spesifikasi *Pompa* pada alat proses

Kode Alat	Keterangan	Daya Pompa
J-121	Pompa formaldehid	0,5764
J-221	Pompa Reaktor ke RVF	0,8309

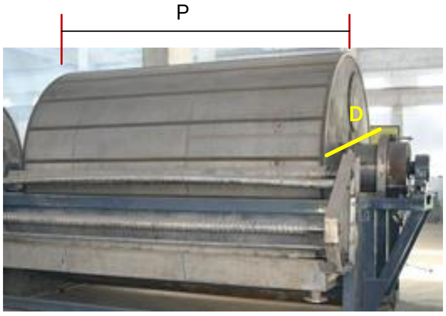
2. *Rotary Vacuum Filter* (RVF-361)

Fungsi : Memisahkan asam ureaformaldehid

Bahan konstruksi : *Stainless Steel*

Alasan : Fase komponen padat – cair, lebih cepat proses pemisahan karena adanya vacum

Gambar :



Gambar 10.4.*Rotary Vacum Filter*

Data Slurry:

- Laju alir massa, ṁ = 33.267,7kg/jam
- Densitas udara, ρ_u = 1,14 kg/m^3 = 0,0715 lb/ft^3
- Berat filtrat = 12.475 kg/jam = 27.501,7 Ib/jam
- Berat cake = 20.792,99 kg/jam = 45.840,23 lb/jam
- Tebal *cake* = 6 mm = 0,006 m *(Perrys, 18-97)*
- Laju alir filtrat = $600 \frac{kg}{m^2}$ jam *(tabel 11.13 walas)*
- Kecepatan putar, N = 2 rpm = 0,03 rps *(Mc cabe, hal 1007)*

Berdasarkan bahan yang akan disaring pada alat rotary vaccum filter, dapat dilihat laju alir filtrat pada tabel 11.13 walas.

Dimana :

Laju alir filtrat $= 600\frac{\text{kg}}{m^2}$ jam

TABLE 11.13. Typical Applications of Industrial Filters

Material	Characteristics	Filtrate Rate kg/(m²)(hr)	Equipment Type[a] A	B	C	D	E	Vacuum (Torr)	Pressure (atm)
Flotation concentrates	minerals, <0.3 m	300–1000	—	—	×	—	×	450–600	—
Sedimentation concentrates	> 0.3 mm	6000–42,000	—	—	×	—	×	50–150	—
Crystals and granules	0.05–0.3 mm	600–2000	—	—	×	—	×	100–300	—
Beverages, juices	worthless solids, use filter aids	150–5000	×	×	—	—	—	—	2.5–3.5
Pigments	smeary, sticky, 0.06 mm	120–300	—	—	×	×	—	500–680	—
		batch mode	×	×	—	—	—		2.5–4
Limestone, oxide minerals	fine, high density	200–1000	—	—	×	—	—	450–600	—
		batch mode	×	×	—	×	—	—	2.5–4
Cane sugar mud	fibrous, viscous		×	×	×	—	—	—	—
Mineral oils	high viscosity, 1–20% bleaching clays	100–1000	—	×	—	—	—	—	4
Liquid fuels	low viscosity, bleaching clays	800–2500	—	×	—	—	—	—	<4
Varnishes, lacquers	cloudy, viscous, solid adsorbents	15–18	×	—	—	—	—	—	1
Fats, oils, waxes	worthless solids, 50–70°C	500–800	×	×	—	—	—	—	—
Sewage sludge	colloidal, slimy	15–150	—	—	×	—	—	550–600	—
Pulp and paper	fibrous, free filtering	150–500	—	—	×	—	—	150–500	—
Cement	fine limestone, shale, clay, etc	300–1000	—	—	×	—	—	450–630	—

[a]Equipment type: (A) filter press; (B) leaf pressure filters, such as Kelly, Sweetland, etc.; (C) continuous vacuum filter; (D) batch rotary filter; (E) continuous rotary filter. (Walas, 1988).

(table 11.13 walas)

air blowback, into the discharge chute, since actual contact with the medium would cause rapid wear. In some cases the filter medium is held by circumferentially wound wires spaced 50 mm (2 in) apart, and a flexible scraper blade may rest lightly against the wire winding. A taut wire in place of the scraper blade may be used in some applications in which physical dislodging of sticky, cohesive cakes is needed.

For a given slurry, the maximum filtration rate is determined by the minimum cake thickness which can be removed—the thinner the cake, the less the flow resistance and the higher the rate. The minimum thickness is about 6 mm (0.25 in) for relatively rigid or cohesive cakes of materials such as mineral concentrates or coarse precipitates like gypsum or calcium citrate. Solids that form friable cakes composed of less cohesive materials such as salts or coal will usually require a cake thickness of 13 mm (0.5 in) or more. Filter cakes composed of fine precipitates such as pigments and magnesium hydroxide, which often produce cakes that crack or adhere to the medium, usually need a thickness of at least 10 mm (0.38 in).

(perrys, 18-97)

Rotary-drum filter. The most common type of continuous vacuum filter is the rotary-drum filter illustrated in Fig. 30.8. A horizontal drum with a slotted face turns at 0.1 to 2 r/min in an agitated slurry trough. A filter medium, such as canvas, covers the face of the drum, which is partly submerged in the liquid. Under the slotted cylindrical face of the main drum is a second, smaller drum with a solid surface. Between the two drums are radial partitions dividing the annular space into separate compartments, each connected by an internal pipe to one hole in the rotating plate of the rotary valve. Vacuum and air are alternately applied to

(Mc cabe, hal 1007)

1. Luas penampang filter, A

Dengan laju alir fitrat yang diinginkan 600 $\frac{\text{kg}}{m^2}$ jam, maka, luas permukaan filter yang dibutuhkanadalah:

$$A = \frac{Berat\ Filtrat}{Laju\ alir\ \ filtrat}$$

A = $\frac{12.475\ \text{kg/jam}}{600\frac{\text{kg}}{m^2}\ \text{jam}}$

= 20.791 m^2

= 223.796 ft^2

Berdasarkan Tabel 11.12b Walas dengan luas permukaan 223.796 ft^2 didapatkan diameter dan panjang alat :

Diameter drum, D = 8 ft = 2,44 m

Panjang drum, P = 9 ft = 2,74 m

TABLE 11.12. Sizes of Commercial Continuous Vacuum Filters

(a) Horizontal Belt Filters[a]

Series	Ft^2 Range	No. Vac. Pans
2600	10–45	1
4600	45–200	1
6900	150–700	1
9600	130–500	2
13,600	600–1200	2

(Eimco).

(b) Rotary Drum, Disk, and Horizontal Filters

Rotary Drum Component Filters[b]

Filter Surface Area (sqft)

Drum[c] Diam (ft)	Length (ft) 4	6	8	10	12	14	16	18	20	22	24
6	76	113	151	189	226						
8			200	250	300	350	400				
10				310	372	434	496	558	620		
12					456	532	608	684	760	836	912

(walas, table 11.14-b hal 354)

2. Volume drum, Vd

Vd $= \frac{\pi}{4} \times D_s^2 \times P$

$= \frac{3{,}14}{4} \times (2{,}44)^2 m x 2{,}74$ m

= 12,81 m^3

Pada *rotary vacuum filter* terjadi pengeringan sebagian cake oleh udara dengan laju alir udara masuk tiap satuan luas permukaan 50 – 80$\frac{m^3}{m^2}$ jam, diambil 65 $\frac{m^3}{m^2}$ jam

(Walas, Table 11-14b)

(b) Typical Air Flow Rates

Type of Filter	Air Flow at 500 Torr Vacuum $[m^3/(h)(m^2)]$
Rotary drum	50–80
Precoat drum	100–150
Nutsche	30–60
Horizontal belt or pan	100–150

3. **Lajur alir udara volumetrik, G**

G = A x Laju alir udara

= 20,791 m^2 x 65 m^3/m^2 jam

= 1.351 m^3/ jam

= 47.724 ft^3/ jam

4. **Lajur alirmassa udara, Wb**

Wb = ρ x G

= 0,07117Ib/ft^3 x 47.724ft^3/ jam

= 3.396,546 Ib/jam = 1.540,663 kg/jam

5. **Penurunan tekanan selama filtrasi**

ΔPt =0,67 tf $(100L)^2$ *(Walas, Pers. 11.28, hal, 318)*

the SCFT data for 0.01 m,

$$\frac{\Delta Pt}{0.67 t_F} = (100L)^2, \quad (11.28)$$

with ΔP in bar. From this relation the filtering time can be found at a specified pressure and cake thickness and when t_F is known.

Dimana :

ΔPt = Penurunan tekanan (bar)

L = Ketebalan cake (m)

tf = Waktu pembentukan cake standar

N = Kecepatan putar

tf $= \frac{1}{N} = \frac{1}{2}$ = 0,5 rpm = 0,0083 rps

Maka,

ΔPt =0,67 tf $(100L)^2$

=0,67x 0,5x (100 x 0,006)^2

=0,1206 bar

=0,118 atm

6. Daya Motor, Hp

$$hp = \frac{3.03 \times 10^{-5} k}{k-1} p_1 q_{fm_1} \left[\left(\frac{p_2}{p_1} \right)^{(k-1)/k} - 1 \right] \qquad (24)$$

(Peters pers. 24 hal 524)

Dimana :

Hp= Daya motor

P1 = tekanan masuk = 500 mmHg = 9,5 psi *(Walas, Tabel 11.18)*

P2 = tekanan keluar = 14,44 psi

TABLE 11.18. Typical Performance Data of Rotary Vacuum Filters

Material	Approximate particle size	Feed solids conc. wt %	Filtration rate (9) kg/(m^2)(hr)	Vacuum Pump (9) m^3/(m^2)(min)	Vacuum Pump (9) mm Hg
Disc filter					
Flotation coal	33–43%–200 mesh	22–26	300–600	1.5	500
Copper concentrates	90%–200 mesh	60–70	250–450	0.5	500
Magnetic concentrates	80–95%–325 mesh	55–65	1000–2000	2.5–3.0	600–650
Coal refuse	35–50%–250 mesh	35–40	100–125	0.6	500
Magnesium hydroxide	15 microns av. size	10–15	40–60	0.6	500
Drum filter					
(1) Sugar cane mud	Limed for flocculation	7–18 by vol.	25–75	0.2	500
$CaCO_3$ mud recausticising	—	35–40	500–600	1.8–2	250–380
(2) Corn starch	15–18 microns, av. size	32–42	110–150	0.9–1	560
Sewage sludge					
Primary	Flocculated	5–8	15–30	0.5	500
Primary digested	Flocculated	4–7	10–20	0.5	509
(3) Leached uranium ore	50–60%–200 mesh Flocculated	50–60	150–220	0.5–	500
Kraft pulp	Long fibre	1–1½	220–300	Barometric leg	
(4) Kaolin clay	98–75%–2 micron	25–35	30–75	0.5	600
Belt drum filter					
(5) Sugar cane mud	Seperan flocculated	7–18 by vol.	90–250	0.2	500
Sewage sludge					
Primary	Flocculated	5–8	30–50	0.5	500
Primary digested	Flocculated	4–7	15–35	0.5	500
Corn gluten	Self flocculating	16–20 oz/U.S. gal	15–30	0.6	500
Corn starch	15–18 microns, av. size	32–42	180–250	0.9–1	500

(Walas, Tabel 11.18)

Ratio specific heat of gas, k =1,4

$$qfm = \frac{\text{laju alir massa}}{\rho udara} = \frac{1.222{,}37 Ib/min}{0{,}0711\ Ib/ft^3} = 17.175{,}252\ ft^3/min$$

$$\mathrm{Hp} = \frac{3{,}03\ x 10^{-5} \mathrm{k}}{k-1} P1.qfm\ [(\mathrm{P1/P2})^{\frac{k-1}{k}} - 1]$$

$$\mathrm{Hp} = 0{,}000106\ x\ 163.164{,}9034\ x\ 0{,}1270$$

Hp = 2,198

3. Reaktor CSTR

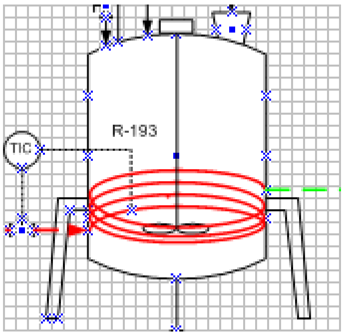
Fungsi : Tempat reaksi Urea dan formaldehid menjadi Urea Formaldehid

Tipe : Silinder vertikal dengan alas dan tutup *ellipsoidal*

Bahan : *Carbon Steel* , SA-285 Cr. C

Jumlah : 1 unit

Gambar :



Gambar C-4 Continous Stired Tank Reactor (CSTR)

Data:

- Laju alir massa, m : 21.885,0126 kg/jam = 156,32 kmol/jam
- Densitas campuran, $\rho_{campuran}$: 976,00265 kg/m^3 = 60,9318 lb$_m$/ft^3
- Temperatur, T : 100°C
- Waktu operasi : 1,5 jam
- Tekanan, $P_{operasi}$: 1 atm = 14,6 psi

Komposisi Bahan masuk reaktor

komponen	F (Kg/Jam)	V(m3/jam
Urea	5910,550	4,4776
Formaldehid	5910,550	7,2552
metanol	2396,169	3,0254
Air	7667,741	7,6677
Total	21.885,012	22,4231

Volume Larutan = 22,42 m^3/jam

1. Laju Alir Volumetrik, Vb

Vb = m / ρ

$$Vb = \frac{21.885,0126 \text{ kg/jam}}{976,0026 \text{ kg/m}^3} = 22,423 \text{ m}^3/\text{jam}$$

2. Volume Reaktor, V_R

Untuk mencapai proses kontinyu, reaktor CSTR ini direncakan dibangun sebanyak 3 tangki, sehingga waktu tinggal nya (τ) 1,5 jam.

Berdasarkan pers. Levenspiel yaitu:

$$\frac{Vr}{FAo} = \frac{\tau}{Ca_o}$$

Vr = Volume tangki yang ditempati cairan

FAo = Laju Alir molar reaktan

Cao = Konsentrasi Reaktan

Konsentrasi Umpan,Cao = $\frac{Fao}{Vb}$ = 6.971 kmol.m^3

Maka,Volume Reaktor

$$Vr = \frac{\tau \times Fao}{Ca_o}$$

V_r = 33,634 m^3

Mempertimbangkan faktor keamanan 20% (tabel 6, Peter. hal 37)

V_R = 33,634 m^3 x 1,2

V_R = 40,361 m^3

$$V_e = \frac{\pi}{6} \times D_t^2 \times H_e$$

3. Dimensi Reaktor

a) Diamater dan Volume Tangki

- **Volume Silinder, Vs**

V_S= $\frac{\pi}{4} \times D_S^2 \times H_S$

H_S = D_S, maka:

V_S= $\frac{\pi}{4} \times D_S^3$

- **Volume Elipsoidal, Ve**

V_e= $\frac{\pi}{6} \times D_t^2 \times H_e$

H_e = 0,25 Dt , maka :

V_e= $\frac{\pi}{24} \times D_t^3$

Volume Reaktor = V Silinder + 2 V *Ellipsoidal*

40,361 m^3 = π/4 x Dt^3 + (2 x π/24 x Dt^3)

40,361 m^3 = 8/24 π Dt^3

$Dt^3 = 38,562\ m^3$

$Dt = 23,378\ m$

$Dt = 133,010\ in$

b) Tinggi Reaktor, H_t

Tinggi Silinder, $H_t = D_t = 3,378\ m = 133,010\ in$

Tinggi Ellipsoidal, He = ¼ Ds = 0,844 m = (Walas, Tabel 18.5)

Tinggi tangki total,

Ht = tinggi silinder + 2 tinggi *ellipsoidal*

Ht = 3,378 m + (2 x 0,844 m)

Ht = 5,067 m

Tinggi cairan di dalam tangki, H_c

$$H_c = \frac{V_{cairan}}{V_{reaktor}} \times H_t$$

$$H_c = \frac{33,634\ m^3}{40,361\ m^3} \times 5,067\ m = 4,22\ m = 13,851\ ft = 166,263\ in$$

c) Tekanan Desain

- Tekanan Hidrostatik

  $P_H = \rho\ g\ H_c$

  $P_H = 976,002\ kg/m^3 \times 9,81\ m^2/s^2 \times 4,22\ m$

  $P_H = 40.393,088\ Pa = 5,856\ psi = 0,398\ atm$

- Tekanan desain, P_D

  $P_D = P_{operasi} + P_H$

  $P_D = 2,5\ atm + 0,398\ atm = 2,898\ atm = 42,608\ psi$

d) Tebal reaktor

Diketahui :

- $P_d = 14,695\ psi$
- Dt = 133,010 in
- S = 13700 psi (Peter, tabel 4 hal 538)
- E = 0,85 (Peter, tabel 4 hal 538)

- C = 0,002 in/tahun, waktu operasi pabrik 10 tahun (Perry's, tabel 23-2)

- **Tebal dinding Reaktor, t_d**

$$t_d = \frac{PD_t}{SE - 0{,}6P} + cn$$ (Walas, Tabel 18.3)

$$t_d = \frac{14{,}695 \text{ psi} \times 133{,}010 \text{ in}}{(13.700 \text{ psi} \times 0{,}85) - (0{,}6 \times 14{,}695 \text{ psi})} + 0{,}002 \text{ in}$$

t_d = 0,169 in = 0,00431 m = 4,317 mm

- **Tebal alas dan tutup elipsoidal, t_e**

$$t_e = \frac{PD_t}{SE - 0{,}2P} + c$$ (Walas, Tabel. 18.3)

$$t_e = \frac{14{,}695 \text{ psi} \times 133{,}010 \text{ in}}{(13700 \text{ psi} \times 0{,}85) - (0{,}2 \times 14{,}695 \text{ psi})} + 0{,}002 \text{ in}$$

t_e = 0,169 in = 0,0043 m = 4,315 mm

4. Desain Pengaduk

Untuk umpan dengan viskositas ≤ 4.000 cP, maka dipilih pengaduk jenis propeler berdaun tiga. Untuk mencegah vorteks, tangki dipasang *bafles* (Wallas, hal 288).

Dari buku Mc. Cabe, hal 242-243

$$\frac{D_a}{D_t} = \frac{1}{3} \quad \frac{H}{D_t} = 1 \quad \frac{J}{D_t} = \frac{1}{12}$$

$$\frac{E}{D_t} = \frac{1}{3} \quad \frac{W}{D_a} = \frac{1}{5} \quad \frac{L}{D_a} = \frac{1}{4}$$

Diketahui: Dt = 3,378 m

- Diameter impeler, Da
  Da = 1/3 Dt
  Da = 1,126 m = 3,694 ft
- Lebar impeler, W
  W = 1/5 Da
  W = 0,225 m = 0,738 ft
- Tinggi pengaduk dari dasar tangki, E
  E = 1/3 Da
  E = 0,375 m = 1,231 ft
- Panjang daun impeler, L
  L = ¼ Da
  L = 0,281 m = 0,923 ft

- Lebar baffle, J

  J = 1/12 Da

  J = 0,563 m = 1,847 ft

Kecepatan Putar Impeler, Nd

$$\frac{Nd}{\left(\frac{\sigma gc}{\rho}\right)^{0,25}} = 1,22 + 1,25\left(\frac{Dt}{Da}\right)$$ Pers.6.18 Treyball ed. 3 hal 154

Interfasial tension, σ = 72,25 dyn/cm = 0,05 lb/ft , (Mc. Cabe. Ed. 5 hal 274)

For water the interfacial tension is 72.75 dyn/cm. The rise velocity of the bubbles may be assumed constant at 0.2 m/s.

gc = 32,2 ft/s^2

$$N_d = 1,22 + 1,25\left(\frac{3,378\ \text{m}}{1,126\ \text{m}}\right) \times \left(\frac{0,05\ \text{lb/ft} \times 32,2\ \text{ft/s}^2}{60,948\ \text{lb/ft}^3}\right)^{0,25}$$

N_d = 2,73 rps = 163,908 rpm

Daya Pengadukan, P

$$N_{Re} = \frac{\rho \times N \times Da^2}{\mu}$$ Mc. Cabe . Pers. 9.17

$$N_{Re} = \frac{60,94\ \text{lb/ft}^3 \times 2,73\ \text{rps} \times (3,694\ \text{ft})^2}{0,00101\ \text{lb. ft/s}}$$

N_{Re} = 2.232.936,792 (turbulen)

Karena N_{Re}> 10.000, maka digunakan persamaan 9.24, Mc. Cabe

$$Pi = \frac{K_T \times N^3 \times Da^5 \times \rho}{gc}$$ Pers. 9.24, Mc. Cabe

Dari tabel 9.3, Mc. Cabe hal 254, diperoleh nilai K_T = 0,87

$$Pi = \frac{0,87 \times (2,73)^3 \times (3,694)^5 \times 60,948\ \text{lb/ft}^3}{32,2\ \text{ft/s}^2}$$

Pi = 23.113,6845 ft.lb$_f$/s

$$Pi = \frac{23.113,6845\ \text{ft.lb}_f\text{/s}}{550} = 42,02\ \text{HP}$$

Maka,dipilih daya pengadukan 45 HP

5. Perhitungan Coil Pemanas

Massa yang digunakan	= 22.078,937 kg
Cp air	=1 J/Kg.K
T_1	= 30°C = 303,15°K
T_2	= 100°C = 373,15°K
Dt	= 3,378 m =337,84 cm
Diamter Coil	= Dt/30
	$=\frac{337,84}{30}$=11,261 cm =0,11 m =4,43 in

Coil ½ in

a"	= 0,021 ft
OD	=0,84 in
ID	=0,622 in
Q	=m x Cp x ΔT
	$=22.078,937\ kg\ x\ \frac{1J}{Kg}.K\ x\ 70K$
	=1.545.525,634 J
	=1465,158 btu

a) Area Perpindahan Panas

$A=\frac{Q}{Ud\ x\ \Delta T}$

$A=\frac{1465,158}{0,87\ x\ 126}$

A=13,365 ft^2

b) Panjang Coil (Lc)

$Lc=\frac{A}{a"}$

$Lc=\frac{13,365}{0,021}$

Lc=636,466 ft

c) Diameter Lilitan Coil

Dc=0,9 x Dt

Dc=0,9 x 337,8469 cm

Dc=304,062cm =3,04 m =9,97 ft

d) Tinggi coil dari dasar tangki (Hc)

Hc=0,15 x Dt

Hc=0,15 x 337,8469 cm

Hc=50,677 cm

e) Luas area satu lilitan (Al)

Al=π x Dc x a”

Al=3,14 x 9,975 x 0,021

Al=0,657 ft^2

f) Jumlah lilitan coil (Nt)

Nt=$\frac{A}{Al}$

Nt=$\frac{13,365}{0,657}$

Nt=20,31 = 20 lilitan

6. Perhitungan Coil Pendingin

Massa yang digunakan	= 4456,75 kg
Cp air	=1 J/Kg.K
T_1	= 100°C = 373,15°K
T_2	= 30°C = 303,15°K
Dt	= 3,378 m =337,84 cm
Diamter Coil	= Dt/30
	=$\frac{337,84}{30}$=11,261 cm =0,11 m =4,43 in

Coil ½ in

a”	= 0,0021 ft
OD	=0,84 in
ID	=0,622 in
Q	=m x Cp x ΔT
	=$4456,75\ kg\ x\ \frac{1J}{Kg}.K\ x\ 70K$
	=311972,5294 J
	=295,749 btu

a) Area Perpindahan Panas (A)

A=$\frac{Q}{Ud\ x\ \Delta T}$

A=$\frac{295,749}{0,87\ x\ 126}$

A=2,697 ft^2

b) **Panjang Coil (Lc)**

$Lc=\frac{A}{a"}$

$Lc=\frac{2,697}{0,021}$

Lc=128,474 ft

c) **Diameter Lilitan Coil (Dc)**

Dc=0,9 x Dt

Dc=0,9 x 337,8469 cm

Dc=304,062cm =3,04 m =9,97 ft

d) **Tinggi coil dari dasar tangki (Hc)**

Hc=0,15 x Dt

Hc=0,15 x 337,8469 cm

Hc=50,677 cm

e) **Luas area satu lilitan (Al)**

Al=π x Dc x a”

Al=3,14 x 9,975 x 0,021

Al=0,657 ft^2

f) **Jumlah lilitan coil (Nt)**

$Nt=\frac{A}{Al}$

$Nt=\frac{2,697}{0,657}$

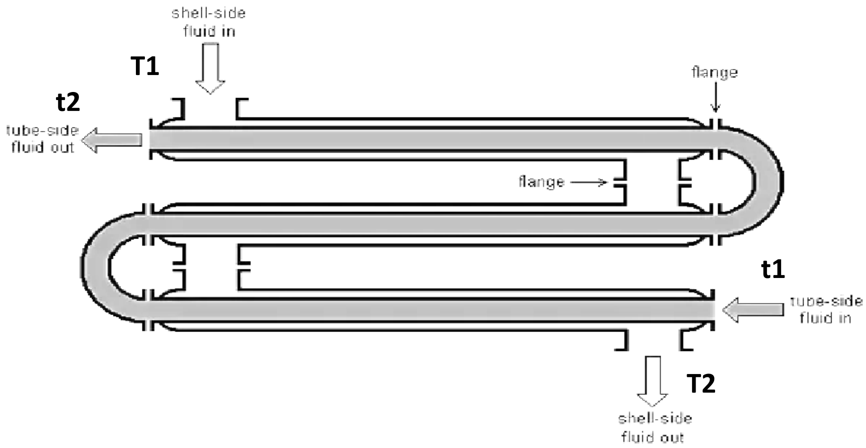
Nt=4,10 = 4 lilitan

4. Kondensor

Fungsi : Untuk mendinginkan produk dari suhu 100°C ke 30°C

Tipe :*Double pipe*

Jumlah : 1 unit



Gambar C-3 *Double Pipe Heat Exchanger*

1. Data dan Kondisi Operasi

A. Beban Panas (Q) = 4.404.010,463 Kj/jam

B. Fluida Panas = Urea Formaldehid

Laju Alir (W_t) = 33.267,7kg/jam = 73.341,97 lb/jam

T_1 = 100 ºC = 212,0 ºF

T_2 = 30 ºC = 86,0 ºF

C. Fluida Dingin = *Cooler*

Laju Alir (W_s) = 17.690,34 kg/jam = 39.000,1264 lb/jam

t1 = 25 ºC = 77 ºF

t2 = 30 ºC = 86 ºF

2. Δt & LMTD

Fluida Panas (F)	Temperatur	Fluida Dingin (F)	Selisih	
212	Tinggi	86	126	ΔT2
86	Rendah	77	9	ΔT1

$$\text{LMTD} = \frac{(\Delta T_2 - \Delta T_1)}{In\frac{\Delta T_2}{\Delta T_1}}$$

= 44,334 °F

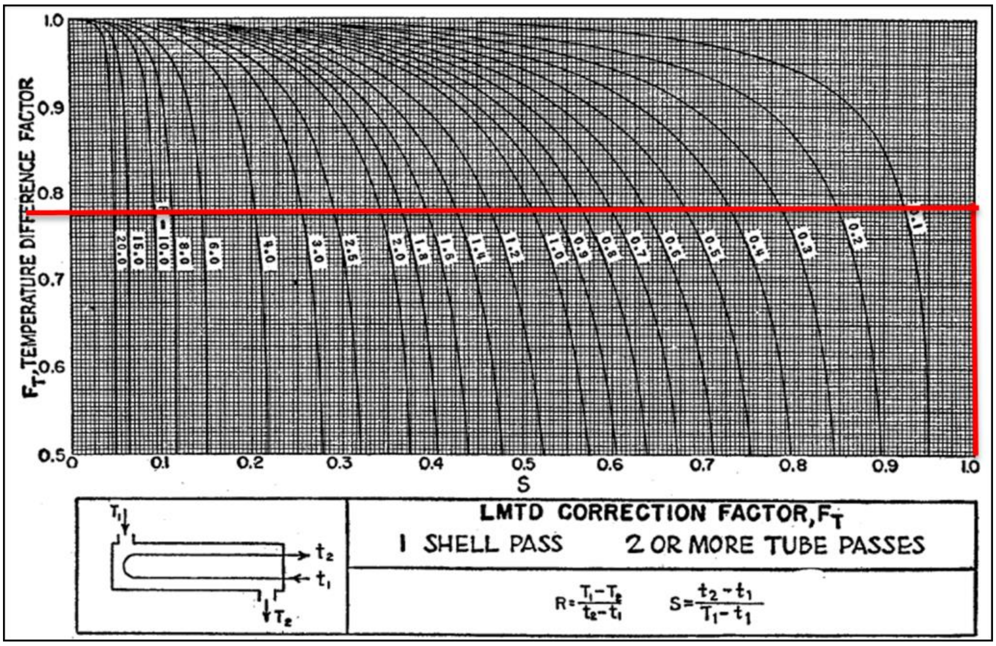
Faktor koreksi LMTD

R $= \dfrac{T_1 - T_2}{t_2 - t_1}$ (D.Q Kern: Pers. 5.14hal. 828)

$= \dfrac{(212-86)°F}{(86-77)°F} = 14$

S $= \dfrac{t_2 - t_1}{T_1 - t_1}$

$= \dfrac{(86-77)°F}{(212-77)°F} = 0{,}067$



Diasumsikan *Heat Exchanger*merupakan HE dengan 1*Shell Pass* dan 2*Tube Pass.* Dari nilai R dan S, maka Faktor Koreksi dapat diperoleh dari gambar 21 D.K. QERN adalah sebagai berikut:

F_T = 078

Sehingga :

ΔT_{LMTD} = LMTD x F_T (D.Q Kern: Pers. 7.42hal. 828)

= 44,334°F x 0,78

= 34,58°F

3. Luas Area Perpindahan Panas, A

$$A = \frac{Q}{U_D \ x \ \Delta T_{LMTD}}$$ (D.Q Kern, pers. 7.6 hal 140)

Berdasarkan Tabel 8, D.Q Kern Hal 840, diperoleh :

Ud = 20 Btu/jam.ft^2.F

Heaters		
Hot fluid	Cold fluid	Overall U_D
Steam	Water	200–700§
Steam	Methanol	200–700§
Steam	Ammonia	200–700§
Steam	Aqueous solutions:	
Steam	Less than 2.0 cp	200–700
Steam	More than 2.0 cp	100–500§
Steam	Light organics	100–200
Steam	Medium organics	50–100
Steam	Heavy organics	6–60
Steam	Gases	5–50¶

* *Light organics* are fluids with viscosities of less than 0.5 centipoise and include benzene, toluene, acetone, ethanol, methyl ethyl ketone, gasoline, light kerosene, and naphtha.

† *Medium organics* have viscosities of 0.5 to 1.0 centipoise and include kerosene, straw oil, hot gas oil, hot absorber oil, and some crudes.

‡ *Heavy organics* have viscosities above 1.0 centipose and include cold gas oil, lube oils, fuel oils, reduced crude oils, tars, and asphalts.

§ Dirt factor 0.001.

‖ Pressure drop 20 to 30 psi.

¶ These rates are greatly influenced by the operating pressure.

$$A = \frac{132.006{,}2336 \ \text{Btu/jam}}{20 \ \text{Btu/jam.ft}^2\text{.F} \ x \ 44{,}334°\text{F}}$$

$= 190{,}867 \ ft^2$

Nilai A < 200 ft^2 maka digunakan tipe perpindahan panas jenis *double pipe.*

*Heater*dirancang dengan menggunakan ukuran pipa = 3 x 2 in IPS, Berdasarkan Tabel 10 D.Q Kern, diperoleh spesifikasi *Tube* dengan :

	Anulus (in)	(ft)	Inner Pipe (in)	(ft)
IPS	3	0,24999	2	0,16666
SC	40	3,3332	40	3,3332
OD (D2)	3,5	0,291655	2,38	0,19833
ID (D1)	3,068	0,25565644	2,067	0,17224
a" (ft2/ft)	**0,917**	0,07641361	**0,622**	**0,05183**

Exchanger, IPS	**Flow Area, in^2**		**Anulus, in**	
	Anulus	**Pipe**	**De**	**De'**
3 x 2	**2,93**	**3,55**	**1,57**	**0,69**

TABLE 6.2. FLOW AREAS AND EQUIVALENT DIAMETERS IN DOUBLE PIPE EXCHANGERS

Exchanger, IPS	Flow area, in.²		Annulus, in.	
	Annulus	Pipe	d_e	d_e'
2 × 1¼	1.19	1.50	0.915	0.40
2½ × 1¼	2.63	1.50	2.02	0.81
3 × 2	2.93	3.35	1.57	0.69
4 × 3	3.14	7.38	1.14	0.53

Anulus, uraformaldehid (Fluida Panas)	**Inner Pipe, *cooler* (Fluida Dingin**
4. ***Flow Area*** D_2 = 3,068 in =0,2557 ft D_1 = 2,38 in = 0,1983 ft $a_S = \pi(D_2^2-D_1^2)/4$ (D.Q Kern: pers. 7.1, hal 138) $= \frac{3,14 \times 0,0654 \text{ in} \times 0,0393 \text{ in}}{4}$ = 0,02043 ft^2 Diameter Ekivalen $Deq = (D_2^2-D_1^2)/D_1$ = 0,1312 ft	4. ***Flow Area*** ID = 2,067 in = 0,1723 ft $a_P = \pi D_1/4$ (D.Q Kern, Table 10 hal 843) $a_P = \frac{3,14 \; x \; 0,0297 in^2}{4}$ (D.Q Kern: pers 7.48, hal 111) =0,0233 ft2
6. ***Mass Velocity*** $G_S = \frac{Ws}{a_s}$ (D.Q Kern: pers 7.2, hal 138) $= \frac{73.341,97 \text{ lb/h}}{0,02043 \text{ ft}^2}$ = 3.589.383,63 lb/hr ft^2	5. ***Mass Velocity*** $Gt = \frac{Wt}{a_t}$ (D.Q Kern: pers 7.2, hal 138) $= \frac{39.000,13 \text{ lb/h}}{0,02329 \text{ ft}^2}$ = 1,674.472,03 lb/hr ft^2

6. ***Reynold Number*** T_{steam} = 149 ^oF μ = 1,5 cp = 1,5 x 2,42 lb/ft.h =3.63 lb/ft.hr $Re_a = \frac{De \text{ x } Ga}{\mu}$ = $\frac{0{,}1312 \text{ ft x } 3.589.383{,}63 \text{ lb/hr ft}^2}{3{,}63 lb/h.ft}$ = 129.772	**6.*Reynold Number*** T_{umpan} = 81,5^oF μ = 1cp = 1x 2,42 lb/ft.h =2,42 lb/ft.hr $Re_t = \frac{De \text{ x } Ga}{\mu}$ = $\frac{0{,}1723 \text{ ft x } 1{,}674.472{,}03 \text{ lb/hr ft}^2}{2{,}42 lb/h.ft}$ = 119.185
7. **Panjang Pipa yang dibutuhkan** **L = A/a’’** = $\frac{190{,}8679 \text{ ft2}}{0{,}917 ft2/ft}$ = 208,1438 ft L/D = $\frac{208{,}1438 \text{ ft}}{0{,}1723 ft}$ =1208,38 jH = 310	7.jH = 290
8. Koefisien Perpindahan Panas Pada t_{steam} = 149 °F c = 0,51 Btu/lb^{o}F (D.Q Kern, Fig. 2 Hal 804) k = 0,0185 Btu/ft.hr^{o}F (D.Q Kern, Tabel 4)	**8. Koefisien Perpindahan Panas** Pada T_{umpan} = 86 °F C = 0,51 Btu/lb^{o}F (D.Q Kern, Fig. 2 Hal 804) k = 0,200 Btu/ft.hr.^{o}F (D.Q Kern, Tabel 4)

Interpolasi =

T (F)	k (Btu/hr.ft^2(^{o}F/ft)
121	0,0137
149	X
150	0,0187

k = 0,0185 Btu/ft.hr^2(^{o}F/ft)

K/D = 0,1412

$$\left(c.\frac{\mu}{k}\right)^{\frac{1}{3}} = \left(0{,}51\,\text{x}\,\frac{1cp}{0{,}0185\text{Btu/ft.hr.}\ ^0\text{F}}\right)^{1/3}$$

= 9,175

K/D = 1,1611

$$\left(c.\frac{\mu}{k}\right)^{\frac{1}{3}} = 0{,}0225$$

9. *Inside Film Coefficient* (h_o)

$$ho = jHx\ \frac{k}{De} x \frac{c\mu}{k}^{1/3} x \frac{\mu}{\mu w}^{0,14}$$

(D.Q Kern: Pers 6.15)

= 401,55 Btu/hr.ft2(^{o}F)

9. *Inside Film Coefficient* (h_{io})

$$ho = jHx\ \frac{k}{De} x \frac{c\mu}{k}^{1/3} x \frac{\mu}{\mu w}^{0,14}$$

(D.Q Kern: Pers 6.15)

= 7,58 Btu/hr.ft2(^{o}F)

Koreksi H_{io} ke permukaan OD

$$h_{i0} = hi.\frac{ID}{OD}.$$

$$= 7{,}58\text{Btu/hr.ft2}\ .^o\text{F}\ x\ \frac{0{,}17224}{0{,}19833}$$

$$= 6{,}58\text{Btu/hr.ft2}\ .^o\text{F}$$

10.Clean overall coefficient U_c

$$U_C = \frac{h_{io} x\, h_o}{h_{io} + h_o}$$

$$= \frac{401{,}55\ \text{x}\ 6{,}58}{401{,}55 + 6{,}58}$$

$$= 6{,}474\ btu/hr.ft^{2.\,o}F$$

11.Dirty Factor, R_d

$$Rd = \frac{U_C - U_D}{U_C\, x U_D} = 0{,}002$$

Koreksi U_D=

$1/U_D$ = $1/U_c$ x Rd

= 1/6,474 +0,002

= 0,154 +0,002

0,156 Btu/hr.ft^2(^{o}F)

401,55	Summary	6,58
Uc	6,474	
Ud	6,391	

Panjang pipa yang dibutuhkan = L = A/a"

= 190,867/0,917

= 208,1438

Dipilih Panjang Hairpin = 12 ft

Maka, Jumlah hairpin yang dibutuhkan =

$$n = \frac{L}{2xPanjanghairpin}$$

= 9 buah

12.Pressure Drop, ΔP	
$Re_s = \frac{DexGa}{\mu}$	Re_t = 119.185,04
$= \frac{0{,}0360x3.589.383{,}63}{3{,}63}$	$f = 0{,}035 + \frac{0{,}246}{(\mathrm{Re}\, s)^\wedge 0{,}42}$
= 35595,769	= 0,0054
$f = 0{,}035 + \frac{0{,}246}{(\mathrm{Re}\, s)^\wedge 0{,}42}$	s = 0,26 (Kern : Fig 6 Hal 809)
	ρ = 0,26 x 62,5

$$0,035+\frac{0,246}{81,58}$$

= 0,0067

s = 1,012 (Kern : Fig 6 Hal 809)

ρ = 1,012 x 62,5

= 63,25

$$\Delta F_{as}=\frac{4FGa\char`^2.La}{2g\rho\char`^2De}$$

= 0,784 psi

V = Ga/3600ρ

= 3.589.383,63/3600 x 63,25

= 15,763 fps

$$\Delta F_{t}=\frac{V\char`^2}{2g}$$

$$=3x\,\frac{248,492}{64,4}$$

= 11,575 ft

$$\Delta F_{a}=\frac{dFas+dFt}{144}$$

=5,429 Psi

= 16,25

$$\Delta F_{as}=\frac{4FGa\char`^2.La}{2g\rho\char`^2De}$$

=33,447 ft

$$\Delta F_{p}=\frac{\Delta F_{as}x\rho}{144}$$

$$\Delta F_{p}=\frac{0,01539x66,875}{144}$$

= 3,7744

Memenuhi karna < 10 Psi

D.Q Kern Fig. 24 Hal 834

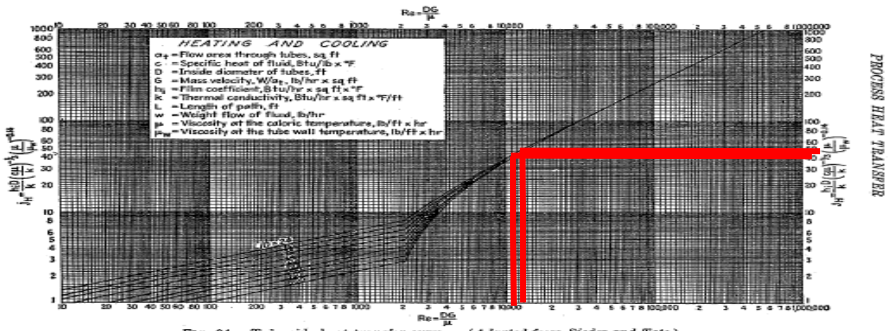


Fig. 24. Tube-side heat-transfer curve. (Adapted from Sieder and Tate.)

D.Q Kern Fig. 2 Hal 804

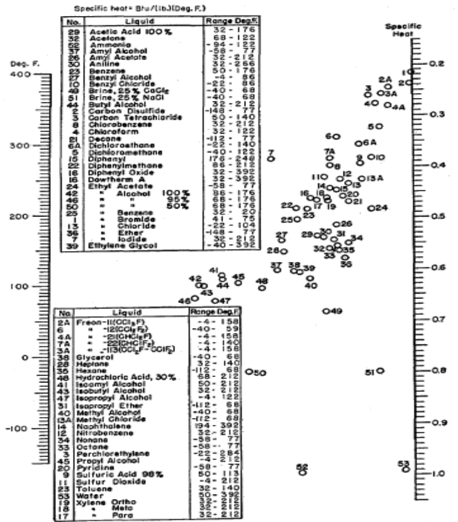


Fig. 2. Specific heats of liquids. (*Chilton, Colburn, and Vernon, based mainly on data from International Critical Tables. Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.*)

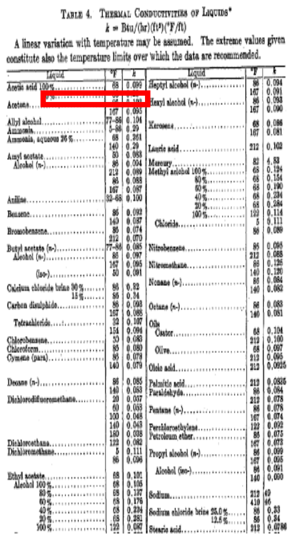


TABLE 4. THERMAL CONDUCTIVITIES OF LIQUIDS*

k = Btu/(hr)(ft²)(°F/ft)

A linear variation with temperature may be assumed. The extreme values given constitute also the temperature limits over which the data are recommended.

B. Spesifikasi Peralatan Utilitas

Dalam suatu pabrik, unit utilitas merupakan bagian yang penting agar proses utama dapat berlangsung sesuai dengan fungsinya. Unit utilitas disediakan berdasarkan kebutuhan operasional pabrik, yaitu :

a. Kebutuhan tenaga listrik
b. Kebutuhan air
c. Kebutuhan steam

1. Kebutuhan Listrik

a. Kebutuhan Listrik Pada Peralatan Proses

Tabel C.14 Kebutuhan Listrik pada Peralatan Proses

Nama Alat	**Daya (HP)**
Reaktor CSTR	42,02
RVF	2,19
Centrifugal Pump	0,96
Crusher	5,36
Total	**50,53**

Kebutuhan listrik pada peralatan proses

= (50,53`Hp× 0,7457 kW/Hp)= 37,68 kW

b. Kebutuhan Listrik Untuk Peralatan Utilitas

Tabel C.15 Kebutuhan Listrik pada Peralatan Utilitas

Keterangan	Daya (hP)
Centrifugal Pump	10,95
Tangki Pelarutan	0,09
Bak Pencampur	0,21
Fan Cooling Tower	5
Boiler	7
Total	**23,27**

Kebutuhan listrik pada peralatan utilitas

= (23,27Hp× 0,746 kW/Hp) = 17,36kW

c. Kebutuhan energi listrik untuk peralatan instrumentasi diperkirakan 50 kwh.

Seperti : Alat – alat pengendali

d. Kebutuhan energi listrik untuk bengkel diperkirakan 100 kwh.

Seperti : Alat pemotong, mesin las, dll

e. Kebutuhan energi listrik untuk penerangan

- Luas area pabrik = 10.000 m^2

  Penerangan rata-rata = 10 watt/m^2

  Total penerangan untuk pabrik= 10.000 m^2 × 10 watt/m^2

  = 100.000 watt

  = 100 kW

- Luas area perumahan, kantor dan fasilitas lain = 5.000 m^2

  - Area perumahan

    Asumsi : 1 rumah karyawan memiliki daya listrik 900 watt

    = 900 watt × 25 unit rumah

    = 22.500 watt

    = 22,5kW

- Area Perkantoran

  Penerangan rata-rata = 10 watt/m^2

  Total penerangan untuk area kantor = 3.000 m^2 × 10 watt/m^2

  = 30.000 watt

  = 30 kW

f. Kebutuhan listrik untuk peralatan kantor dan komunikasi

   Seperti :

   - 20 unit komputer (@ 300 watt) = 6.000 watt
   - 5 unit TV (@ 50 watt) = 250 watt
   - 10 unit AC (@ 300 watt) = 3.000 watt
   - 12 unit dispenser (@ 300 watt) = 3.600 watt
   - 5 unit kulkas (@ 110 watt) = 550 watt
   - 2 unit mesin photo kopi (@ 800 watt) = 1.600 watt
   - Dan lain-lain = 800 watt

   Jumlah = 15.800 watt = 15,8 kW

Total kebutuhan listrik :

= (37,68+ 17,36 + 50 +100 + 100 + 22,5 + 30 + 15,8)kW

= 373,34 kW

Faktor keamanan 20% (Peters, hal 37)

Kebutuhan listrik sebenarnya = 1,2 x 508,29 kW

= 609,94 kW

2. Kebutuhan Air

a. *Steam*

Tabel C.16 Kebutuhan *Steam* untuk Proses

Nama Alat	Kebutuhan (kg/jam)
Reaktor CSTR	66.236,81
Total	**66.236,81**

b. Air Pendingin

Tabel C.18 Kebutuhan Air Pendingin

Nama Alat	Kebutuhan (kg/jam)
Coil Pendingin	13.370,2513
Kondensor	53.071,024
Total	**66.441,28**

c. Air sanitasi

Air sanitasi digunakan untuk :

- Perumahan

  Diperkirakan kebutuhan air perorangan ± 100 L/hari atau setara dengan 26,4 gallon/hari. Pabrik Urea formladehid ini memiliki 25 unit rumah yang disediakan untuk golongan tertentu. Asumsi 1 orang karyawan memiliki 4 orang anggota keluarga, sehingga jumlahnya menjadi 100 orang, maka kebutuhan air setiap jam:

  $= 100 \times\ 25 \frac{l}{Hari} \times\ \frac{1\,Hari}{24\ jam}$

  = 416,4 liter/jam = 0,4164 m^3/jam

  = 416,4 kg/jam

- Perkantoran

  Kebutuhan air perorangan ±25 L/hari atau 6,6 gallon/hari, dengan jumlah karyawan 121 orang, kebutuhan air setiap jam adalah :

  $= 121 \times\ 25 \frac{l}{Hari} \times\ \frac{1\,Hari}{24\ jam}$

  = 125,96 liter/jam = 0,1259 m^3/jam

  = 125,96 kg/jam

- Laboraturium diperkirakan sebanyak = 30 kg/jam
- Poliklinik diperkirakan sebanyak = 30 kg/jam
- Masjid dan kantin diperkirakan sebanyak = 50 kg/jam

  Total kebutuhan air untuk sanitasi = 652,355 kg/jam

Total Kebutuhan Air

Kebutuhan Air per jam

- Air pendingin = 66.441,28 kg/jam
- Air umpan boiler = 66.236,81 kg/jam

- Air sanitasi = 652,355 kg/jam

Total = 133.330,44 kg/jam

Pada saat operasi kontinu sejumlah air akan disirkulasikan dengan asumsi kehilangan air sebesar ± 10%

Air make up untuk *cooling tower* dan boiler = sejumlah air make up

= 10%(umpan boiler+cooler)

= 13.267,8088 kg/jam

Jumlah air saat start up = total kebutuhan air

= 146.598,25 kg/jam

Jumlah air yang hilang = air sanitasi + air *make up*

= (652,355+13.267,8088) kg/jam

= 13.920,16 kg/jam

Jumlah air yang dibutuhkan pada saat operasi kontinu adalah

= faktor keamanan × jumlah air yang hilang

= 1,2 × 13.920,16 kg/jam

= 16.704,1965 kg/jam

3. Spesifikasi Peralatan Utilitas

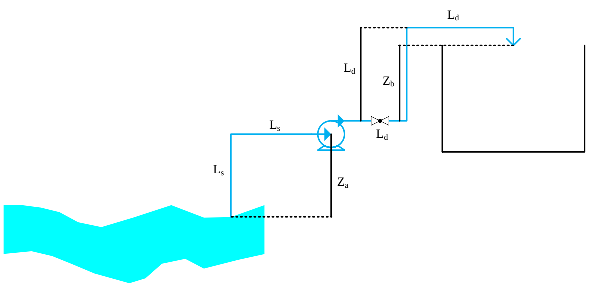
3.1 Pompa (P-1001)

Fungsi : Mengalirkan air dari sungai ke bak penampungan

Tipe : *Centriugal pump*

Bahan : *Carbon Steel*

Gambar :



Data :

- Laju alir massa, m : $16.704,20 \frac{kg}{jam} = 36.832,75 \frac{lb}{dt}$
- Densitas air, ρ : 1000 kg/m^3 = 62,4 lb/ft^3
- Viskositas air, μ : 1 cP = 0,0007 lb/ft.dtk
- Tinggi pompa terhadap cairan masuk, Za : 3 m = 10 ft
- Tinggi pompa terhadap cairan keluar, Zb : 3,33 m = 11 ft
- Panjang pipa hisap, Ls : 8 m = 26,25 ft
- Panjang pipa buang, Ld : 10 m = 32,8 ft
- Faktor keamanan 10%

Laju alir volumetrik, Q_v

Q_p = m + (0,1 x m)

= 36.832,75 lb/jam + (0,1 x 36.832,75)

= 10.438,78 lb/jam

$Q_v = \frac{Q_p}{\rho}$

$= \frac{11,2545\ lb/s}{62,447\ lb/f3}$

= 0,1802 ft^3/dt

Diameter optimum, D_{opt}

Asumsi aliran turbulen

$D_{opt} = 3,9*Q_v^{0,45}*\rho^{0,13}$ (Peter, Pers 14.15)

$= 3,9*(0,10)^{0,45}*(62,4)^{0,13}$

= 2,39 in = 2,5 in

Berdasarkan Tabel 11 Kern, diperoleh pipa baja dengan ukuran sebagai berikut :

	Suction (a)	Discharge (b)
IPS	12 in Sch 40	
OD	11,9380 in = 0,9948 ft	11,9380 in = 0,9948 ft

ID	12,7500 in = 1,0625 ft	12,7500 = 1,0625 ft
a''	0,7773 ft^2	

Kecepatan aliran, V

Va = Vb, karena ukuran pipa hisap dan pipa buang sama

$$V = \frac{Q_v}{a''}$$

$$= \frac{0{,}1802\ ft^3/dt}{0{,}7773\ ft^2} = 0{,}2319 \text{ ft/dt}$$

$$\frac{V^2}{2g_c} = \frac{0{,}2319\text{^}2}{2\times 32{,}17} = 0{,}0008 \text{ ft-lb}_f\text{/lb}$$

Bilangan Reynolds, N_{Re}

$$N_{Re} = \frac{\rho \times V \times D}{\mu}$$

= 21.436

Rugi Gesek

- **Pipa hisap (*suction*)**

Pada pipa hisap, rugi gesek timbul akibat gesekan dengan kulit pipa, serta pengaruh *fitting* dan *valve*.

- Rugi gesek akibat kulit

$h_{fsa} = f\ \frac{L_s}{r_H}\frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

$r_H = \frac{ID}{4}$

$= \frac{0{,}9948 ft}{4} = 0{,}2487$ ft

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

k = 0,00015 ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID}$ = 0,0002

f = 0,004 (Mc Cabe, Fig. 5.9)

Maka,

h_{fsa} $= 0{,}004 \times \frac{26{,}2467 ft}{0{,}2487} \times 0{,}0008\ ft.lb_f/lb$

$= 0{,}0004$ ft-lb$_f$/lb

- Rugi gesek akibat *fitting*

h_{ffa} $= K_f \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.67)

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.1)

Maka,

h_{ffa} $= ((1\ x\ 0{,}9)) \times 0{,}0008\ ft.lb_f/lb$

$= 0{,}0007519$ ft-lb$_f$/lb

- **Pipa buang (*discharge*)**

Pada pipa buang, rugi gesek timbul akibat gesekan dengan kulit pipa, serta pengaruh *fitting* dan *valve*.

- Rugi gesek akibat kulit

h_{fsb} $= f \frac{L_d}{r_H} \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.56)

r_H $= \frac{ID}{4}$

$= \frac{0{,}9948\ ft}{4} = 0{,}2487$ft

Material yang digunakan untuk konstruksi pipa adalah *commercial steel pipe*, dimana

k = 0,00015 ft (Mc Cabe, Fig. 5.9)

$\frac{k}{ID}$ $= 0{,}0002$

f = 0,004 (Mc Cabe, Fig. 5.9)

Maka,

h_{fsb} = 0,0004 ft-lb$_f$/lb

- Rugi gesek akibat *fitting dan valve*

h_{ffb} $= K_f \frac{V^2}{2g_c}$ (Mc Cabe, Pers 5.67)

K_f (*elbow* 90°) = 0,9 (Mc Cabe, Tabel 5.108)

Total K_f = (3x0,9)+(1x10) = 12,7

Maka,

h_{ffb} = 12,7 x 0,0008 ft lbf/lb

= 0,0106 ft-lb_f/lb

Sehingga, total rugi gesek adalah

= $h_{fsa} + h_{fsb} + h_{ffa} + h_{ffb}$

= 0,0122 ft-lb_f/lb

Daya pompa (BHP)

Daya pompa dapat dihitung dengan menggunakan Persamaan Bernoulli :

$$\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c} + \eta W_p = \frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c} + h_f$$

Atau

$$\eta W_p = \left(\frac{P_b}{\rho} + \frac{gZ_b}{g_c} + \frac{\alpha_b V_b^2}{2g_c}\right) - \left(\frac{P_a}{\rho} + \frac{gZ_a}{g_c} + \frac{\alpha_a V_a^2}{2g_c}\right) + h_f$$

Dimana

$P_a = P_b$

$V_a = V_b$

$\rho_a = \rho_b$

$g/g_c = 1$

$\alpha_a = \alpha_b$

η = 52% (Peters, Fig. 14.37)

Sehingga persamaan di atas dapat disederhanakan menjadi :

$\eta W_p = (Z_b - Z_a) + h_f$

$0{,}52W_p$ = (10,9 – 9,8)ft + 0,0122 ft-lb_f/lb

W_p = 2,1631 ft-lb_f/lb

BHP = $\frac{W_p \times m}{550}$

= 0,0443 HP

Daya motor (MHP)

MPH $= \frac{BHP}{\eta}$

η = 80 % (Peters, Fig 14.38)

MPH $= \frac{0{,}0443\ HP}{0{,}80}$

= 0,0553 HP

Dengan cara yang sama, maka diperoleh daya pada masing-masing pompa untuk peralatan utilitas seperti pada Tabel C.19 berikut ini.

Tabel C.19 Daya Pompa pada Peralatan Utilitas

Kode Alat	Keterangan	Daya (hP)
P-1002	Pompa dari bak penampungan	0,29
P-1003	Pompa dari tangki pelarutan alum	0,2
P-1004	Pompa dari tangki pelarutan kapur tohor	0,2
P-1005	Pompa dari tangki pelarutan kaporit	0,2
P-1006	Pompa dari unit pengolahan *raw water*	0,16
P-1007	Pompa dari *sand filter*	0,18
P-1008	Pompa dari bak penampungan air bersih	0,7
P-1009	Pompa dari *softener tank*	0,26
P-1010	Pompa dari tangki air demin	2,7
P-1011	Pompa dari *plant* masuk *cooling tower*	2,7
P-1012	Pompa dari *cooling tower*	0,4
P-1013	Pompa dari *deaerator*	1,1
P-1014	Pompa kondensat masuk boiler	0,8

4.1 Bak Penampung Air Sungai (BP-1101)

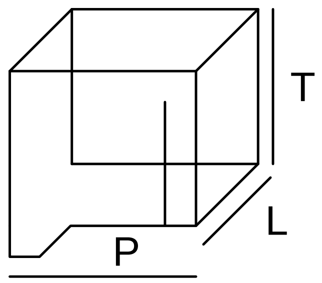
Fungsi : Menampung air sungai sebelum diolah menjadi air bersih

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 1 buah

Konstruksi : Beton bertulang

Gambar :



Data :

- Laju alir massa, m : 16.704,20 kg/jam
- Densitas, ρ : 1000 kg/m^3
- Waktu tinggal : 24 jam

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{16.704,20 \frac{kg}{jam}}{1000\ kg/m^3} = 16,7042\ m^3/jam$$

Dimensi bak

V = 16,7042 m^3/jam x 24 jam

= 400,90 m^3

Faktor keamanan 10%

Volume bak = 400,90 x 0,9 = 445,445 m^3

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

222,723 m^3 = 3T x 2T x T

6T^3 = 222,723 m^3

T = 3,336 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 10,007 m

Lebar = 2T = 6,67 m

Tinggi = T = 3,336 m

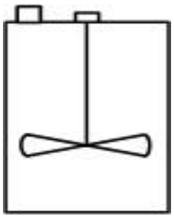
4.2 Tangki Pelarutan Alum (TP-2202)

Fungsi : Tempat melarutkan alum ($Al_2(SO_4)_3$)

Jenis : Silinder vertikal dengan alas dan tutup datar

Konstruksi : *Fiber*

Gambar :



Data :

- Laju alir massa, m = 16.704,2kg/jam
- Densitas alum, ρ = 1000 kg/m^3 = 68,98 lb/ft^3
- Laju alir volumetrik, Q = 16,704 m^3/jam = 16.704,2 liter/jam
- Faktor keamanan 20%

Kebutuhan alum

Kekeruhan air sungai Bontang yaitu sebesar 25, NTU(blh.kaltim.go.id)

Untuk kekeruhan 22,5-30 NTU penggunaan alum yaitu sebesar 20 mg/ltr = 2x10^{-5} kg/ltr air

Kebutuhan alum = 2x10^{-5} kg/ltr air x 16.704,2 ltr/jam

= 0,334 kg/jam

= 8,02 kg/hari

= 17,68 lb/hari

Alum yang digunakan berupa larutan alum dengan konsentrasi 25% berat.

Berat larutan alum $= \frac{8{,}02\ kg/hari}{0{,}25}$= 32,07 kg/hari

Volume alum 25% $= \frac{32{,}07\ kg/hari}{1620\ kg/m^3}$= 0,0198 m^3/hari

Faktor keamanan 10%

Maka,

Volume alum total= 0,0198 x 0,9= 0,022 m^3/hari

Kapasitas tangki

Kebutuhan alum direncanakan untuk pemakaian selama 7 hari.

Volume tangki 0,02 m^3/hari x 7 hari

= 0,15 m^3

= 153,98 liter

Dimensi tangki,

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s \qquad H_s = D_t$$

Maka,

$$V_s = \frac{\pi}{4}\ x\ D_t^3$$

- **Diameter Tangki, D_t**

$$V_r = V_s + Ve$$

$$V_r = \left(\frac{\pi}{4}\ x\ D_t^3\right)$$

$$= 0{,}916\ D_t^3$$

$$D_t^3 = \frac{V_t}{0{,}916}$$

$$= \frac{0{,}15}{0{,}916}$$

$$D_t = \sqrt[3]{\frac{0{,}67}{0{,}196}} = 0{,}552\ m$$

- **Tinggi *tangki*, H_r**

Tinggi silinder,

$H_s = D_t = 0{,}552\ m$

- **Tinggi Cairan, H_c**

$$H_c = \frac{Volume\ cairan}{Volume\ Tangki}\ x\ H_t$$

$$H_c = \frac{0{,}138}{0{,}15}\ x\ 0{,}69\ m$$

= 0,62 m

- **Tekanan Cairan, P_c**

$P_c = \rho \,.\, g \,.\, h$

$P_c = 1620\ kg/m^3 x\ 9.810\ m/s\ x\ 0{,}62\ \ m$

$= 9.867{,}91\ kg/m\ dt^2$

$= 0{,}097\ atm$

- **Tekanan Disain, P_d**

$P_d = P_{operasi}\ x\ P_c$

$= 1\ atm + 0{,}097\ atm$

$= 1.097\ atm$

$= 16{,}131\ psi$

- **Tebal dinding tangki, t_d**

$$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3)$$

Tekanan desain, P	: 16,1316 psi	
Jari-jari tangki, R	: 10,86 in	
Allowable stress, S	: 13700 psi	(Peter, Tabel 4 Hal 538)
Efisiensi pengelasan, E	: 0,85	(Peter, Tabel 4 Hal 538)
Faktor korosi yang diizinkan	: 0,002 in/thn	(Perry's Tabel 23-2)
Tahun digunakan	: 10 tahun	

Maka,

$$t_d = \frac{16{,}1316\ psi\ x\ 10{,}86 in}{(13700\ psi\ x\ 0.85) - (0.6\ x\ 16{,}1316\ \ psi)} + 0.002\ in/thn\ x\ 10\ thn$$

$= 0{,}035\ in$

Perencanaan pengaduk

Jenis pengaduk yang digunakan adalah propeller berdaun tiga tanpa sekat, dari Mc Cabe Hal. 243 diperoleh :

- Da/D_t = 0,333
- C/D_t = 0,333

- Wa/D_a = 0,20
- L/Da = 0,25

Dari persamaan di atas, maka diperoleh hasil sebagai berikut :

- Diameter tangki, D_t = 1,81 ft
- Diameter impeller, D_a = 0,333 D_t = 0,6036 ft
- Tinggi impeller dari dasar tangki, C = 0,333 D_t = 0,6036 ft
- Lebar impeler, Wa = 0,20 D_t = 0,1207 ft
- Panjang daun pengaduk = 0,25 Dt = 0,1509 ft

Kecepatan putar pengaduk, N

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1{,}22 + 1{,}25\left(\frac{D_B}{d}\right)$$ (Treybal, Pers 6.18)

σ : 72,75 dyne/gr = 0,05 lbf/ft (Mc Cabe, Hal 274)

g_c : 32,2 ft/dt^2

Maka,

$$N = \frac{\left(1{,}22 + 1{,}25\left(\frac{1{,}81\ ft}{0{,}603\ ft}\right)\left(\frac{0{,}05\frac{lb}{ft}x\ 32{,}2}{101{,}164\frac{lb}{ft^3}}\right)^{0{,}25}\right)}{0{,}603\ ft}$$

= 4,227 rps

$$N_{Re} = \frac{\rho \times N \times D_a{}^2}{\mu}$$ (Mc Cabe, Pers 9.17)

$$= \frac{101{,}1639\frac{lb}{ft^3} \times 4{,}227\ rps \times (0{,}6063 ft)^2}{0{,}00045\frac{lb}{ft}.dt} = 344.711{,}69$$

Karena bilangan Reynold > 10.000, mkaa:

K_T = 0,87 (McCabe, Tabel 9.2)

Maka, daya pengadukan:

$$P = \frac{K_T N^3 D_a{}^5 \rho}{g_c}$$ (Mc Cabe, Pers 9.20)

$$= \frac{0,87 \times (4,227)^3 (0,603)^5 \times 101,164}{32,2}$$

= 16,5595 lb.ft/dt

= 0,0301 HP ≈ 0,1 HP

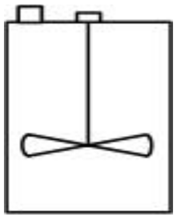
4.3 Tangki Pelarutan Kapur Tohor (TP-2201)

Fungsi : Tempat melarutkan kapur tohor ($Ca(OH)_2$)

Jenis : Silinder vertikal dengan alas dan tutup datar

Konstruksi : *Fiber*

Gambar :



Data :

- Laju alir massa, m = 16.704,2 kg/jam
- Densitas kapur tohor, ρ = 1117,19 kg/m^3 = 69,6396 lb/ft^3
- Laju alir volumetrik, Q = 16,7042 m^3/jam = 16.704,2 liter/jam
- Faktor keamanan 10%

Kebutuhan kapur tohor

Kekeruhan air sungai bontang yaitu sebesar 25 NTU(blh.kaltimtimprov.go.id)

Untuk kekeruhan 14,73-27,26 NTU penggunaan kapur tohor yaitu sebesar 15 mg/ltr = 1,5x10^{-5} kg/ltr air

Kebutuhan kapur tohor = 1x10^{-5} kg/ltr air x 16.704,2ltr/jam

= 0,25 kg/jam

= 6,01kg/hari

Alum yang digunakan berupa larutan alum dengan konsentrasi 40% berat.

Berat larutan kapur tohor = $\frac{6,01\ kg/hari}{0,40}$= 15,03 kg/hari

Volume kapur tohor40%=$\frac{15,03\ kg/hari}{1117,19 kg/m^3}$= 0,013 m^3/hari

Faktor keamanan 20%

Maka,

Volume kapur tohor total= 0,013 / 0,8= 0,0168 m^3/hari

Kapasitas tangki

Kebutuhan tohor direncanakan untuk pemakaian selama 7 hari.

Volume tangki ‘= 0,01682 m^3/hari x 7 hari

= 0,117 m^3

Dimensi tangki,

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s \qquad\qquad H_s = D_t$$

Maka,

$$V_s = \frac{\pi}{4}\ x\ D_t^3$$

- **Diameter Tangki, D_t**

$$V_r = V_s$$

$$V_r = \left(\frac{\pi}{4}\ x\ D_t^3\right)$$

$$= 0{,}9158\ D_t^3$$

$$D_t^3 = \frac{V_t}{0{,}9158}$$

$$= \frac{0{,}12}{0.9158}$$

$$D_t = \sqrt[3]{\frac{0{,}52}{0{,}9158}} = 1{,}656\ ft = 0{,}505\ m$$

- **Tinggi *tangki*, H_r**

Tinggi silinder,

$H_s = D_t = 0{,}505\ m$

- **Tinggi Cairan, H_c**

$H_c = \frac{Volume\ cairan}{Volume\ Tangki}\ x\ H_t$

$H_c = \frac{0,094}{0,12}\ x\ 0,63$

$Hc = 0,5047$ m

- **Tekanan Cairan, P_c**

  $P_c = \rho\ .\ g\ .\ h$

  $P_c = 1117,19\ kg/m^3 x\ 9.810\ m/s\ x\ 0,50472\ \ m$

  $= 5.531,522\ kg/m\ dt^2$

  $= 0,0546\ atm$

- **Tekanan Disain, P_d**

  $P_d = \ P_{operasi}\ x\ P_c$

  $= 1\ atm + 0,0546\ atm$

  $= 1.0546\ atm$

  $= 15,50\ psi$

- **Tebal dinding tangki, t_d**

  $t_d = \frac{PR}{SE - 0.6P} + C$ (Walas, Tabel 18.3)

Tekanan desain, P	: 15,5025 psi	
Jari-jari tangki, R	: 9,9354 in	
Allowable stress, S	: 13700 psi	(Peter, Tabel 4 Hal 538)
Efisiensi pengelasan, E	: 0,85	(Peter, Tabel 4 Hal 538)
Faktor korosi yang diizinkan	: 0,002 in/thn	(Perry's Tabel 23-2)
Tahun digunakan	: 10 tahun	

Maka,

$$t_d = \frac{15,5025\ psi\ x\ 9,9354in}{(13700\ psi\ x\ 0.85) - \ (0.6\ x\ 15,5025\ \ psi)} + 0.002\ \ in/thn\ x\ 10\ thn$$

$= 0,033\ in$

$= 0,00084\ m$

$= 0,84\ \ mm$

Perencanaan pengaduk

Jenis pengaduk yang digunakan adalah propeller berdaun tiga tanpa sekat, dari Mc Cabe Hal. 243 diperoleh :

- Da/D_t = 0,30
- C/D_t = 0,33
- Wa/D_a = 0,20
- L/Da = 0,25

Dari persamaan di atas, maka diperoleh hasil sebagai berikut :

- Diameter tangki, D_t = 1,65 ft
- Diameter impeller, D_a = 0,30 D_t = 0,5519 ft
- Tinggi impeller dari dasar tangki, C = 0,33 D_t = 0,5519 ft
- Lebar impeler, Wa = 0,20 D_t = 0,11 ft
- Panjang daun pengaduk = 0,25 Dt = 0,138 ft

Kecepatan putar pengaduk, N

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1{,}22 + 1{,}25\left(\frac{D_B}{d}\right)$$ (Treybal, Pers 6.18)

σ : 72,75 dyne/gr = 0,05 lbf/ft (Mc Cabe, Hal 274)

g_c : 32,2 ft/dt^2

Maka,

$$N = \frac{\left(1{,}22 + 1{,}25\left(\frac{1{,}6559\ ft}{0{,}5519 ft}\right)\left(\frac{0{,}05\frac{lb}{ft} x\ 32{,}2}{69{,}6396\frac{lb}{ft^3}}\right)^{0{,}25}\right)}{0{,}5519\ ft}$$

= 4,8588rps

$$N_{Re} = \frac{\rho \times N \times {D_a}^2}{\mu}$$ (Mc Cabe, Pers 9.17)

$$= \frac{69{,}6396\ \frac{lb}{ft^3} \times 4{,}8588\ rps \times (0{,}5519 ft)^2}{0{,}000311\frac{lb}{ft}.dt} = 33147{,}808$$

Karena bilangan Reynold > 10.000, mkaa:

$K_T = 0{,}87$ (McCabe, Tabel 9.2)

Maka, daya pengadukan:

$$P = \frac{K_T N^3 {D_a}^5 \rho}{g_c} \quad \text{(Mc Cabe, Pers 9.20)}$$

$$= \frac{0{,}87 \times (4{,}8588)^3 (0{,}5519)^5 \times 69{,}639}{32{,}2}$$

= 11,068 lb.ft/dt

= 0,0201 HP ≈ 0,1 HP

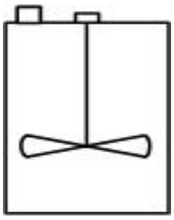
4.4 Tangki Pelarutan Kaporit (TP-2203)

Fungsi : Tempat melarutkan kaporit ($Ca(OCl)_2$)

Jenis : Silinder vertikal dengan alas dan tutup datar

Konstruksi : *Fiber*

Gambar :



Data :

- Laju alir massa, m = 16.704,2 kg/jam
- Densitas kaporit, ρ = 1182,564 kg/m^3 = 73,7149 lb/ft^3
- Laju alir volumetrik, Q = 16.704,2 liter/jam
- Faktor keamanan 10%

Kebutuhan kaporit

Kekeruhan air sungai Bontang yaitu sebesar 25 NTU (blh.kaltimprov.go.id)

Untuk kekeruhan 22,5-27,26 NTU penggunaan kaporit yaitu sebesar 20 mg/ltr = 2x10^{-5} kg/ltr air

Kebutuhan kaporit = 2x10^{-5} kg/ltr air x 16.704,2 liter/jam

= 0,334 kg/jam

= 8,018 kg/hari

Kaporit yang digunakan berupa larutan kaporit dengan konsentrasi 40% berat.

Berat larutan kaporit = $\frac{8{,}018\ kg/hari}{0{,}40}$ = 20,045 kg/hari

Volume kaporit40% = $\frac{20{,}045\ kg/hari}{1182{,}56\ kg/m^3}$ = 0,0169 m^3/hari

Faktor keamanan 20%

Maka,

Volume kaporit total = 0,0169/0,8= 0,0212 m^3/hari

Kapasitas tangki

Kebutuhan kaporit direncanakan untuk pemakaian selama 7 hari.

Volume tangki = 0,02 m^3/hari x 7 hari

= 0,15 m^3 = 148,3167 liter

Dimensi tangki,

- **Volume silinder, V_s**

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s \qquad H_s = D_t$$

Maka,

$$V_s = \frac{\pi}{4}\ x\ D_t^3$$

- **Diameter Tangki, D_t**

$$V_r = V_s$$

$$V_r = \left(\frac{\pi}{4}\ x\ D_t^3\right)$$

$$= 0{,}9158\ D_t^3$$

$$D_t^3 = \frac{V_t}{0{,}9158}$$

$$= \frac{0{,}15}{0{,}9185}$$

$$D_t = \sqrt[3]{\frac{0{,}65}{0{,}9158}}$$

$$= 0{,}545\ m$$

- **Tinggi *tangki*, H_r**

  Tinggi silinder,

  $H_s = D_t = 0{,}545\ m$

- **Tinggi Cairan, H_c**

  $$H_c = \frac{Volume\ cairan}{Volume\ Tangki}\ x\ H_t$$

  H_c = 0,545 m

- **Tekanan Cairan, P_c**

  $P_c = \rho\ .g\ .h$

  $P_c = 1182{,}56\ kg/m^3 x\ 9.810\ m/s\ x\ 0{,}545m$

  $= 6323{,}49\ kg/m\ dt^2$

  $= 0{,}062\ atm$

- **Tekanan Disain, P_d**

  $P_d = P_{operasi}\ x\ P_c$

  $= 1\ atm + 0{,}062\ atm$

  $= 1{,}062\ atm$

  $= 15{,}617\ psi$

- **Tebal dinding tangki, t_d**

  $$t_d = \frac{PR}{SE - 0.6P} + C \qquad (Walas, Tabel\ 18.3)$$

Tekanan desain, P	: 15,617 psi	
Jari-jari tangki, R	: 10,73 in	
Allowable stress, S	: 13700 psi	(Peter, Tabel 4 Hal 538)
Efisiensi pengelasan, E	: 0,85	(Peter, Tabel 4 Hal 538)
Faktor korosi yang diizinkan	: 0,002 in/thn	(Perry's Tabel 23-2)
Tahun digunakan	: 10 tahun	

Maka,

$$t_d = \frac{15{,}17\ psi\ x\ 10{,}73 in}{(13700\ psi\ x\ 0.85) - (0.6\ x\ 15{,}61\ \ psi)} + 0.002\ in/thn\ x\ 10\ thn$$

$$= 0.034\ in$$

$$= 0.000874\ m$$

$$= 0{,}874\ \ mm$$

Perencanaan pengaduk

Jenis pengaduk yang digunakan adalah propeller berdaun tiga tanpa sekat, dari Mc Cabe Hal. 243 diperoleh :

- Da/D_t = 0,30
- C/D_t = 0,33
- Wa/D_a = 0,20
- L/Da = 0,25

Dari persamaan di atas, maka diperoleh hasil sebagai berikut :

- Diameter tangki, D_t = 1,788 ft
- Diameter impeller, D_a = 0,30 D_t = 0,596 ft
- Tinggi impeller dari dasar tangki, C = 0,33 D_t = 0,596 ft
- Lebar impeler, Wa = 0,20 D_t = 0,149 ft
- Panjang daun pengaduk = 0,25 Dt = 0,149 ft

Kecepatan putar pengaduk, N

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1{,}22 + 1{,}25\left(\frac{D_B}{d}\right)$$ (Treybal, Pers 6.18)

σ : 72,75 dyne/gr = 0,05 lbf/ft (Mc Cabe, Hal 274)

g_c : 32,2 ft/dt^2

Maka,

$$N = \frac{\left(1{,}22 + 1{,}25\left(\frac{1{,}788\ ft}{0{,}596\ ft}\right)\left(\frac{0{,}05\frac{lb}{ft}x\ 32{,}2}{73{,}71\frac{lb}{ft^3}}\right)^{0{,}25}\right)}{0{,}596\ ft}$$

= 4,464 rps

$$N_{Re} = \frac{\rho \times N \times {D_a}^2}{\mu}$$ (Mc Cabe, Pers 9.17)

$$= \frac{73{,}71\ \frac{lb}{ft^3} \times 4{,}464\ rps \times (0{,}596 ft)^2}{0{,}00052 \frac{lb}{ft}.dt} = 224.889{,}478$$

Karena bilangan Reynold > 10.000, mkaa:

K_T = 0,87 (McCabe, Tabel 9.2)

Maka, daya pengadukan:

$$P = \frac{K_T N^3 {D_a}^5 \rho}{g_c}$$ (Mc Cabe, Pers 9.20)

$$= \frac{0{,}87 \times (4{,}464)^3 (0{,}596)^5 \times 73{,}71}{32{,}2}$$

= 13,35 lb.ft/dt

= 0,024 HP ≈ 0,1 HP

4.5 Unit Pengolahan *Raw Water* (BP-2102)

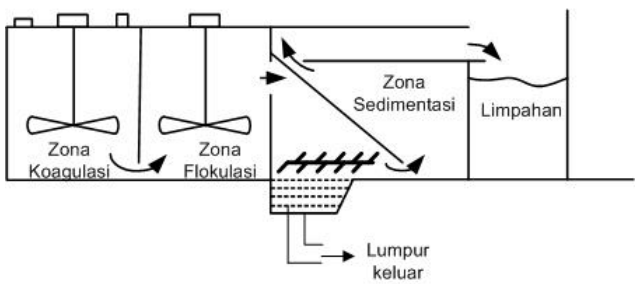
Fungsi : Tempat pencampuran, pembentukan dan pengendapan flok-flok yang terkandung dalam air

Bentuk : Persegi panjang

Konstruksi : beton bertulang dengan ketebalan 15 cm

Jumlah : 1 unit

Gambar :



Data :

- Laju alir massa, m = 16.771,347 kg/jam
- Densitas, ρ = 1.000 kg/m^3 = 62,43 lb/ft^3
- Viskositas, μ = 1 cP = 0,00067 lb/ft.dtk
- Waktu tinggal = 2 jam
- Faktor keamanan 10%

Kapasitas bak

$$Q = \frac{m}{\rho}$$

$$= \frac{16.771{,}347 \frac{kg}{jam}}{1000\ kg/m^3} = 16{,}7713\ m^3/jam$$

Direncanakan jumlah bak 2 = 16,7713/2 =8,385

Faktor keamanan 20%

$$\text{Kapasitas bak} = \frac{8{,}385 \frac{m3}{jam} x\ 2 jam}{0{,}8} = 20{,}9642\ m3$$

Dimensi bak

Perbandingan dimensi bak penampung yaitu P : L : T = 4 : 1 : 1

Volume bak = panjang x lebar x tinggi

$20{,}9642 m^3$ = 4T x 1T x 1T

$4T^3$ = $20{,}9642 m^3$

T = 1,737m

Sehingga diperoleh dimensi bak :

Panjang = 4T = 6,948 m

Lebar = T =1,737 m

Tinggi = T = 1,737 m

4.5.1 Bak Pencampur

Direncanakan panjang bak pencampur adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak pencampur= 20% x 6,948m = 1,389 m

Sehingga ukuran bak pencampur adalah

Panjang = 1,389 m

Lebar = 1,737 m

Tinggi = 1,737 m

Volume bak pencampur = P x L x T

= $4{,}19\ m^3$

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter impeller = 0,579 m
- Panjang daun pengaduk = 0,144m
- Lebar daun pengaduk = 0,115 m
- Tinggi impeler dari dasar tangki = 0,579 m
- Kecapatan pengadukan = 1,048 rps
- Daya motor = 0,0875 hp

4.5.2 Bak Pembentukan Flok

Direncanakan panjang bak pembentukan flok adalah 20% dari panjang bak unit pengolahan *raw water*.

Panjang bak pembentuk flok = 20% x 6,948m = 1,389 m

Sehingga ukuran bak pencampur adalah

Panjang = 1,389 m

Lebar = 1,737 m

Tinggi = 1,737 m

Volume bak pencampur = P x L x T

= 4,192 m^3

Perencanaan sistem pengaduk

Dimensi Pengaduk

- Diameter impeller = 0,579 m
- Panjang daun pengaduk = 0,145 m
- Lebar daun pengaduk = 0,115 m
- Tinggi impeler dari dasar tangki = 0,579 m
- Kecapatan pengadukan = 1,048 rps
- Daya motor = 0,087 hp

4.5.3 Bak Sedimentasi

Direncanakan panjang bak sedimentasi adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak sedimentasi = 30% x 6,948m = 2,08 m

Sehingga ukuran bak sedimentasi adalah

Panjang = 2,08 m

Lebar = 1,74 m

Tinggi = 1,74 m

Volume bak sedimentasi = P x L x T

= 6,29m^3

4.5.4 Bak Limpahan Air Bersih

Direncanakan panjang bak limpahan air bersih adalah 30% dari panjang bak unit pengolahan *raw water*.

Panjang bak sedimentasi = 30% x 6,948 m = 2,08 m

Sehingga ukuran bak sedimentasi adalah

Panjang = 2,08 m

Lebar = 1,74 m

Tinggi = 1,74 m

Volume bak sedimentasi = P x L x T

= 6,29 m^3

4.6 *Sand Filter* (SF-3101)

Fungsi : Menyaring sisa-sisa flok yang berasal dari bak penampung berpelampung (*float chamber*)

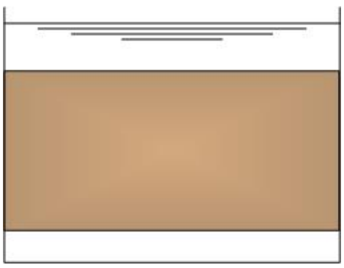
Bentuk : Persegi panjang

Konstruksi : beton bertulang

Isi : pasir silica, karbon dan batu-batu kecil

Jumlah : 2 unit

Gambar :



Data :

- Laju alir massa, m = 16.771,3474 kg/jam
- Densitas, ρ = 1000 kg/m^3
- Waktu tinggal = 30 menit = 0,5 jam
- Faktor keamanan 20%

Kapasitas bak

$$Q = \frac{m}{\rho}$$

$$= \frac{16.771,3474\ \frac{kg}{jam}}{1000\ kg/m^3} = 16,7713\ m^3/jam$$

Faktor keamanan 20%

Volume bak = 16,7713 x 0,5 = 8,385 m3

Direncanakan digunakan 2 unit bak penampungan

Kapasitas tiap bak = 8,385/2 = 4,1928 m3

Kapasitas bak = 4,1928/0,8 = 5,241 m3

Kondisi filter

Porositas unggun, ε = 0,4

Air yang terisi dalam unggun 80% dari air masuk.

Volume ruang kosong = Volume yang terisi air

Volume unggun = V air yang mengisi unggun + V partikel

Air yang mengisi unggun = 80% x 5,241 m^3

= 4,193 m^3

Volume partikel $= \frac{4,193\ m^3}{0,4} = 10,4821\ m^3$

Maka, volume unggun = (4,193 + 10,4821) m^3

= 14,6749m^3

Volume air yang tidak mengisi unggun= 20% x volume unggun

= 2,935 m^3

Sehingga,

Volume bak = V unggun + V air yang tidak mengisi unggun

= 14,6749 m^3 + 2,935 m^3 = 17,6099 m^3

Dimensi bak *sand filter*

Perbandingan dimensi bak *sand filter* yaitu P : L : T = 3 : 2 : 3

Volume bak = panjang x lebar x tinggi

17,6099 m^3 = 3T x 2T x 3T

$18T^3$ = 17,6099 m^3

T = 0,992 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 2,978 m

Lebar = 2T = 1,985 m

Tinggi = 3T = 2,978 m

4.7 Bak Penampung Air Bersih (BP-3203)

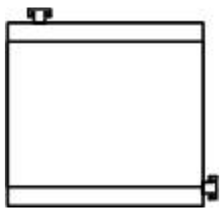
Fungsi : Menampung air bersih hasil penyaringan di *sand filter*

Jenis : Bak berbentuk empat persegi panjang

Jumlah : 2 unit

Konstruksi : Beton bertulang dengan ketebalan 15 cm

Gambar :



Data :

- Laju alir massa, m : 16.771,3474 kg/jam
- Densitas, ρ : 1000 kg/m^3 = 62,428 lbm/ft^3
- Waktu tinggal : 24 jam

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{16.771,3474 \frac{kg}{jam}}{1000\ kg/m^3} = 16,7713\ m^3/jam$$

Dimensi bak

V = 16,7713 m^3/jam x 24 jam

= 402,5123 m^3

Direncanakan digunakan bak penampung = 2 buah

Kapasitas setiap bak = 402,5123 m^3 /2 = 201,25 m^3

Faktor keamanan 10%

Volume bak = 201,2562 x 0,1 = 223,618 m^3

Perbandingan dimensi bak penampung yaitu P : L : T = 3 : 2 : 1

Volume bak = panjang x lebar x tinggi

223,618 m^3 = 3T x 2T x T

$6T^3$ = 223,618 m^3

T = 3,34 m

Sehingga diperoleh dimensi bak :

Panjang = 3T = 10,02 m

Lebar = 2T = 6,68 m

Tinggi = T =3,34 m

4.8 *Softener Tank* (*Kation + Anion Exchanger*) (ST-4101)

Fungsi : Tempat pertukaran kation dan anion dalam air dengan H^+ dan OH^- dari resin

Jenis : Silinder vertikal dengan tutup dan alas *dished*

Jumlah : 2 unit

Konstruksi : *Carbon steel*(SA-515), Grade 55 C-Si

Gambar :

Data :

- Laju alir massa, m :16.118,9924 kg/jam

- Densitas, ρ : 1000 kg/m^3

Laju alir volumetrik, Q

$$Q = \frac{m}{\rho}$$

$$= \frac{16.118{,}9924\ \frac{kg}{jam}}{1000\ kg/m^3} = 16{,}119\ m^3/jam$$

Faktor keamanan 20%

Maka,

$$Q = \frac{16{,}119}{0{,}8}$$

= 20.148 m^3/jam

= 88,7187 galon/menit (GPM)

Berdasarkan data kapasitas yang diperoleh, maka dipilih alat *softener tank* tipe FST-50000 dengan spesifikasi sebagai berikut (Marlo, 2012)

Laju alir maksimum : 300GPM

Ukuran pipa aliran air antar tangki : 3in

Ukuran pipa aliran air keluar tangki : 2 in

Volume resin : 40 ft^3

Diameter : 8 m

Tinggi : 5 m

Model No.	Capacity (M3/H)	Power (kw)	Recovery Rate (%)	Total land area LX W X H (mm)
FST-250	0.25	1.5	50	2500X1000X2800
FST -500	0.5	1.5	50	2500X1000X2800
FST -1000	1	2	50	3500X1200X2800
FST-2000	2	4	50-60	6500X1500x2800
FST-3000	3	4.5	55-65	7500X1500X2800
FST-4000	4	6.5	55-65	7500X1500X2800
FST-5000	5	11	60-70	10000X2500X3500
FST-6000	6	11	60-70	10000X2500X3500
FST-8000	8	18	60-70	10000X3500X3500
FST-10000	10	20	60-70	10000X4000X3800
FST-20000	20	30	70-75	15000X5000X5000
FST-30000	30	40	70-75	20000X6000X5000
FST-50000	50	50	70-75	30000X8000X5000

4.9 Tangki Air Demin (TDW-4201)

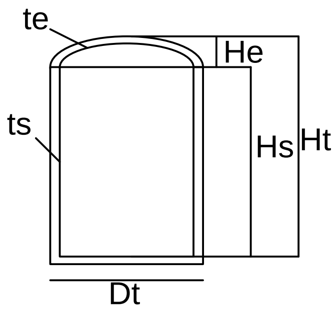
Fungsi : Tempat penyimpanan air bersih bebas mineral

Jenis : Silinder vertikal dengan alas datar dan tutup *dished*

Jumlah : 1 unit

Konstruksi : *Carbon Steel* (SA-515), Grade 55 C-Si

Gambar :



Data :

- Laju alir massa, m : 16.118,992 kg/jam
- Densitas, ρ : 1.000 kg/m^3
- Waktu tinggal : 0,5 jam

Kapasitas tangki

$$V = \frac{m \times t}{\rho}$$

$$= \frac{16.118{,}992\ \frac{kg}{jam} \times 0{,}5\ jam}{1.000\ kg/m^3} = 4{,}0297\ m^3$$

Faktor keamanan 20%

Maka,

$$V = 1{,}25 \times 4{,}0297 = 5{,}0372\ m^3$$

Dimensi tangki

Volume silinder

$$V_s = \frac{\pi}{4}\ x\ D_t^2\ x\ H_s$$

$$V_s = \frac{\pi}{4}\ x\ D_t^3$$

Hs = Dt

Volume *elipsoidal*

$$V_e = \frac{\pi}{6} \, x \, D_t^2 \; x \, H_e$$

He = ¼ Dt

$$V_e = 1{,}1785 \; x \; D_t^3$$

Diameter Tangki

$$V_t = V_s + V_e$$

$$V_t = \left(\frac{\pi}{4} \, x \, D_t^3\right) + \left(0.1308 \; x \; D_t^3\right)$$

$$V_t = 1{,}571429 \; x \; D_t^3$$

$$D_t^3 = \frac{V_t}{1{,}571429}$$

$$D^3 = \frac{V_t}{1{,}571429}$$

$$D^3 = \frac{5{,}0372}{1{,}571429} = 5{,}70 \; m^3$$

D_t = 1,47 m

H_s = 1,5 D_t = 2,21 m

H_e = ¼ Dt = 0,36 m

H_c = 1,769 m

H_t = 2,21168 m

Tebal dinding tangki

$$t_t = \frac{PR}{SE - 0{,}6P} + C \qquad \text{(Walas, Tabel 18.3)}$$

Tekanan desain :

P = Pop + $(\rho \times g \times H_c)$

= 1 atm + (1000 kg/m^3 x 9,81 m/dt^2 x 1,769 m)

= 1 atm + 0,1713 atm

= 1,1713atm

= 17,2181 psi

Tekanan desain, P : 17,2181 psi

Jari-jari tangki, R : 29,0246 in

Allowable stress, S : 13.700 psi (Walas, Tabel 18.4)

Efisiensi pengelasan, E : 0,85 (Peter, Tabel 4 Hal 538)

Faktor korosi yang diizinkan : 0,002 in/thn (Perry's Tabel 23-2)

Maka,

$t_t = \frac{PR}{SE-0,6P} + C$

$t_t = \frac{18,67\ psi \times 29,024\ in}{(13.700\ psi \times 0,85)-(0,6 \times 17,2181\ psi)} + 0,002 \frac{in}{tahun} \times 10 tahun$

= 0,063 in

= 1,60 mm

Tebal tutup *ellipsoidal*, t_e

$t_e = \frac{PD}{2SE-0,2P} + C$ (Walas, Tabel 18.3)

$= \frac{17,2181\ psi \times 58,04924\ in}{(2 \times 13.700 \times 0,85)-(0,2 \times 17,2181\ psi)} + 0,002 \frac{in}{tahun} \times 10\ tahun$

= 0,06 in

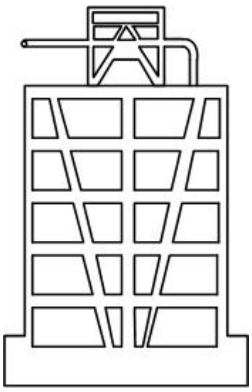
= 1,6 mm

4.10 *Cooling Tower*(CT-5101)

Fungsi : Mendinginkan air sirkulasi yang telah dipakai untuk pendinginan

Jenis : *Induced draft cooling tower*

Gambar :



Data :

- Laju alir massa, m : 66.441,2751 kg/jam
- Densitas, ρ : 1000 kg/m^3 = 62,428 lb/ft^3
- Temperatur masuk : 48°C = 113°F
- Temperatur keluar : 24°C = 77°F
- h_{udara} = h_u : 22 Btu/lb udara kering

- h_{air} = h_a : 105 Btu/lb udara kering

Berdasarkan Fig. 12.2 dan Fig. 12.3 Perry's, diperoleh data sebagai berikut :

- Temperatur bola basah : 65°F
- Temperatur bola kering : 72°F
- T_{av} = 68,5°F

Laju alir volumetrik, Wc

$$W_c = \frac{m}{\rho}$$

$$= \frac{66.441,2751 \frac{kg}{jam}}{1000 kg/m^3} = 66,441 \text{ m}^3\text{/jam} = 292,5320 \text{ galon/menit}$$

Cooling tower yang digunakan adalah tipe *induced draft cooling tower* dengan aliran *counter current.*

Cooling range = 118,4°F – 75,2°F = 43,2°F

Luas *tower,* A

Kandungan air, C_a = 1,5 gall/menit.ft² (Perry's, Fig 12-14)

Luas menara $= \frac{W_c}{c_a}$

$$= \frac{292,532 \ GPM}{1,5 \frac{gall}{menit.ft^2}} = 195,0214 \text{ ft}^2$$

Factor keamanan 10%

Maka, A = 1,1 x195,0214 = 216,6904 ft²

Daya yang dibutuhkan *fan*

Performa standar menara 97%

Maka, daya yang didapatkan = 0,037 HP/ft² (Perry's, Fig 12-15)

Sehingga,

$$P_{act} = 0,037 \text{ HP/ft}^2 \times 216,6904 \text{ ft}^2$$

$$= 5 \text{ HP}$$

Dimensi *tower*

Dt $= \frac{A \times \sqrt{Z_t}}{C_t \times \sqrt{C_t}}$ (Perry's, Pers 12-15)

Dengan, Dt = koefisien bahan menara

A = luas menara

Zt = tinggi menara

Ct = koefisien performa menara = 5 (Perry's, Hal 12-21)

Untuk menghitung Dt digunakan persamaan :

$\frac{W_L}{Dt} = 90{,}85 \left(\frac{\Delta h}{\Delta T}\right) \sqrt{\Delta t + (0{,}3124 \Delta h)}$ (Perry's, Pers 12-16)

Dengan Δh = perubahan panas = $h_a - h_u$ = 83 Btu/lb

ΔT = perubahan temperatur melalui menara

= 43,2°F

W_L = beban air pada menara

= 66.441,2751 kg/jam = 14650 lb/jam

Δt = T keluar – T bola kering

= 5°F

Maka,

$$\frac{146503{,}0116}{Dt} = 90{,}85 \left(\frac{83}{43{,}2}\right) \sqrt{5 + (0{,}3124 \times 83)}$$

Dt = 155,5117 ft = 47,43 m

Tinggi tower, Z_t:

$Z_t = \sqrt{\frac{Dt\left(Ct\sqrt{Ct}\right)}{A}}$

$Z_t = \sqrt{\left(\frac{155{,}5117\ \left(5\sqrt{5}\right)}{216{,}6904}\right)}$

Z_t = 64,38 ft = 19,63 m

Direncanakan D = Z_t/1,5

Sehingga, diameter menara = 13,09 m

4.11 Unit Pengolahan Air Umpan Boiler

Air umpan boilermerupakan air yang digunakan untuk menghasilkan steam. Kebutuhan air umpan boiler= 66.236,81 kg/jam. Jika kondensat yang dapat diregenerasi 66.236,81 kg/jam dan asumsi 90 % yang dapat disirkulasikan kembali, maka kondensat yang disirkulasikan adalah = 66.236,81 x 90%kg/jam = 59.613,13 kg/jam

Maka air *make-up* yang dibutuhkan oleh boileradalah

= (66.236,81 – 59.613,13) kg/jam

= 6.623,681 kg/jam

4.11.1 *Deaerator* (DE-5201)

Fungsi : Menghilangkan gas terlarut dalam air umpan boiler

Bentuk : Silinder horizontal dengan tutup dan alas *ellipsoidal*

Konstruksi : *Carbon steel* (SA-515), Grade 55 C-Si

Jumlah : 1 unit

Gambar :

Data :

- Air umpan boiler : 66.236,81 kg/jam = 146052,2 lb/jam

Direncanakan akan didesain *duo-tank deaerator* yang mampu mengolah 146052,2 lb/jam air umpan boiler.

Kondensat yang bisa diregenerasi 90% = 90% x 66236,81

` = 59613,13 kg/jam

Air make up yang dibutuhkan boiler adalah = 66236,81 – 59613,13

= 6623,681 kg/jam

Berdasarkan kapasitas tersebut, diperoleh data sebagai berikut.

- Tipe : SM15 D
- Diameter : 48 in = 1,219 m
- Panjang tangki : 11,6 ft = 3,538 m

Table 1-7. General Information, Duo-Tank Deaerator (Spraymaster Only)

Model No.	Rating lb/hr	Gallons to Overflow 10 Minute Storage	Tank Size
SM7 D	7,000	230/160	36" x 9'0"
SM15 D	15,000	300	48' x 11'6"
SM30 D	30,000	600	54" x 15'0"
SM45 D	45,000	900	60" x 17'3"
SM70 D	70,000	1,400	66" x 22'8"
SM100 D	100,000	2,000	72" x 26'0"
SM140 D	140,000	2,800	84' x 25'0"
SM200 D	200,000	4,000	96' x 26'3"
SM280 D	280,000	5,600	108' x 28'4"

NOTES:
Duo-Tank Deaerators have a 10 minute storage capacity in each section.
200 and 280 Models use two internal sprays.

4.11.2 *Boiler* (B-5301)

Fungsi : Menghasilkan *steam*

Tipe : *Fire-tube boiler*

Konstruksi : *Carbon Steel*(SA-515), Grade 55 C-Si

Jumlah : 1 unit

Gambar :

Data-data :

- Jumlah steam dibutuhkan = 66.236,81 kg/jam
- Kondensat yang diregenerasi =59.613,13 kg/jam
- Air make-up = 6.623,681 kg/jam

- Steam yang akan dihasilkan diproduksi 30 % berlebih

Jumlah steam yang dihasilkan = 1,3 x 66.236,81 kg/jam

= 86.107,86 kg/jam

Berdasarkan data jumlah steam yang dihasilkan, maka dipilih boiler tipe THW-I 210 –HTE dengan spesifikasi sebagai berikut.

- Daya operasi : 21 HP
- Efisiensi 91,5%
- Temperatur *flue gas* : 210°C
- Tekanan operasi : 10 bar
- Panjang : 7,92 m
- Lebar : 3,65 m
- Tinggi : 5,24 m

LAMPIRAN D
ANALISA EKONOMI

Analisa ekonomi dihitung untuk menentukan jumlah modal yang dibutuhkan untuk mendirikan dan mengoperasikan pabrik serta tinjauan kelayakan suatu pabrik.

1. Perhitungan Jumlah Modal

Prarancangan pabrik Urea Formaldehid dari Urea dan Formalin dengan kapasitas 150.000 ton/tahun ini mengolah bahan padat dan cairan. Dalam hal ini, untuk menentukan jumlah modal yang dibutuhkan untuk mendirikan dan mengoperasikan pabrik diperoleh dari hasil perkiraan dengan metoda *percentage delivered equipment cost* untuk *solid-fluid processing plant* (Peters, 1991).

1.1 Perhitungan Harga Alat

Untuk menghitung harga peralatan pada tahun 2025 ditentukan dengan persamaan :

$$Harga\ Sekarang = Hargaawal \times \left(\frac{indekshargasekarang}{indekshargaawal}\right)$$ (Peters, 1991)

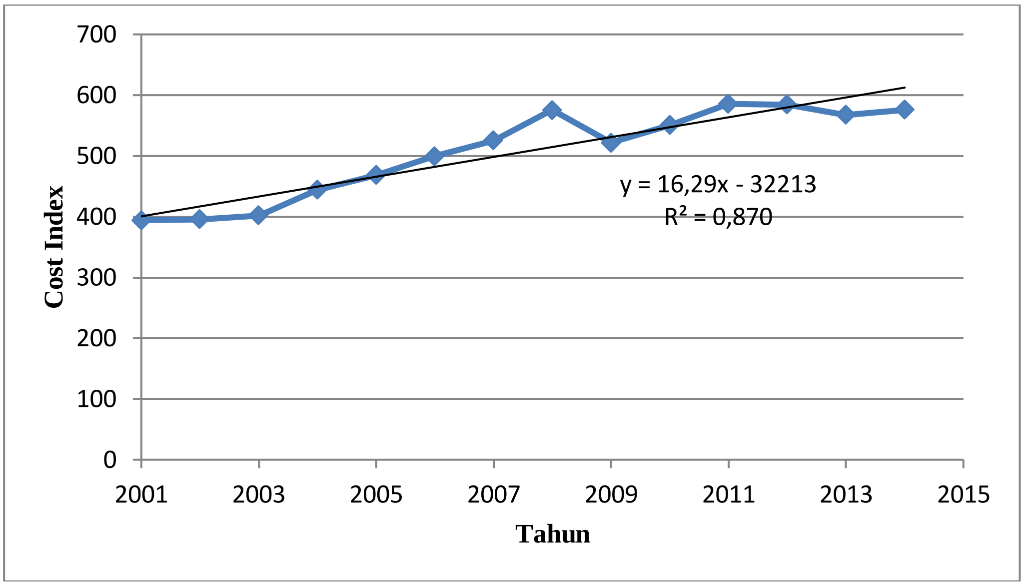
Daftar indeks harga rata-rata tahunan menurut *Engineering Plant Cost* dapat dilihat pada Tabel D.1 dan Gambar D.1 di bawah ini.

Tabel D.1 Daftar Indeks Harga Rata-Rata Tahunan

Tahun	Indeks Harga (Cost Index)
2001	394,3
2002	395,6
2003	402
2004	444,2
2005	468,2
2006	499,6
2007	525,4
2008	575,4
2009	521,9
2010	550,8
2011	585,7
2012	584,6
2013	567,3
2014	576,1

(Sumber : Chemical Engineering Plant Cost Index, http://www.chemengonline.com/pci-home)

Berdasarkan Tabel D.1 maka diperoleh grafik seperti yang terlihat pada Gambar D.1 sebagai berikut.



Gambar D.1 Grafik Hubungan *Cost Index*terhadap Tahun

Persamaan yang diperoleh sesuai Gambar D.1 adalah :

y = 16,29x – 32213

Dengan menggunakan persamaan di atas dapat dicari harga indeks pada tahun penghitugan dan perancangan pabrikyaitu tahun penghitungan2018 dan perancangan pabrik tahun 2025 yaitu :

x = 2014

y = 576,1

x = 2025

y = 16,29(2025) – 32213

y = 774,25

Contoh perhitungan harga peralatan :

Harga *Storage Tank* dengan kapasitas 358,086 m^3pada tahun 2018 adalah US$ 359000

Nilai indeks harga tahun 2014 : 576,1

Nilai indeks harga tahun 2025: 726,3

Harga satu buah *Storage Tank* tahun 2025 adalah :

$$= 359000 \times \left(\frac{774{,}25}{576{,}1}\right)$$

$$= \ 359000 \times 1{,}34$$

$= US\$ \ 482478 \ =$ Rp 6.955.527827

Diketahui : 1 Dollar = Rp 14.416,25 (18 Juli 2018)

Dengan cara yang sama, diperoleh perkiraan harga peralatan utama dan utilitas seperti yang terlihat pada Tabel D.2 dan Tabel D.3 di bawah ini.

Tabel D.2 Daftar Perkiraan Harga Peralatan Proses

No	Komponen	Faktor Pengali	Jumlah	Harga/Unit (US$)	Harga/Unit (Rp)
1.	Tangki Formaldehid	1,343950703	1	13305,11196	191.809.820
2.	Pompa		2	26207,03871	377.807.222
3.	Silo		1	9004,46971	129.810.686
4.	Kondensor		3	38840,17532	559.929.677
5.	Screw Conveyor		1	26744,61899	385.557.114
6.	Conveyor		1	93001,38865	1.340.731.269
7.	Bucket Elevator		1	25131,87815	362.307.438
8.	Reaktor		3	1300675,49	18.750.863.038
9.	Rotary vacuum filter		1	8466,889429	122.060.795
10.	Crusser		1	11961,16126	172.435.091
TOTAL			15	1,553,338	22.393.312.151

Sumber : (matche.com)

Total harga peralatan proses :

- Harga peralatan proses, A : US$ 1.553,338= Rp 22.393.312.151
- Biaya transportasi dan asuransi, 12%A : US$ 186,401 = Rp 2.687.197.458
- Pajak bea cukai, 10%A : US$ 155,334 = Rp 2.239.331.215 +

Total : US$ 1,895,073 = Rp 27.319.840.824

Tabel D.3 Daftar Perkiraan Harga Peralatan Utilitas

No.	Komponen	Faktor Pengali	Jumlah	Harga/Unit (US$)	Harga/Unit (Rp)	Total Harga (US$)	Total Harga (Rp)
1.	Centrifugal Pump (12 in)	1,343950703	15	23.385	337.120.290	491080	7.079.526.094
2.	bak Penyimpanan air sungai		2	24.179	348.570.755	48358	697.141.510
3.	Tangki pelarutan Alum		1	7.237	104.332.917	7237	104.332.917
4.	Tangki pelarutan Kaporit		1	7.237	104.332.917	7237	104.332.917
5.	Tangki Pelarutan kapur tohor		1	7.237	104.332.917	7237	104.332.917
6.	Unit Raw Water		2	11.762	169.567.631	23525	339.135.262
7.	Sand Filter		2	36.190	521.722.711	72380	1.043.445.422
8.	BakPenyimpanan air bersih		2	24.179	348.570.755	48358	697.141.510
9.	Softener Tank		2	65.141	939.093.130	130283	1.878.186.260
10.	Tangki Air Demin		1	127.866	1.843.350.497	127866	1.843.350.497
11.	Colling Tower		1	41.335	595.889.175	41335	595.889.175
12.	Deaerator		1	43.427	626.055.629	43427	626.055.629
13.	Tangki Bahan Bakar		1	125.178	1.804.601.039	125178	1.804.601.039
14	Boiler		1	100.124	1.443.417.335	100124	1.443.417.335
Total			**33**			**1133316**	**16.338.166.745**

Sumber : (www.alibaba.com/www.matches.com)

Total harga peralatan utilitas :

- Harga peralatan utilitas, B : US$ 1,133,316= Rp 16.338.166.745

- Biaya transportasi dan asuransi, 12% B: US$ 135,998 = Rp 1.960.580.009
- Pajak bea cukai, 10% B : US$ 113,332= Rp 1.633.816.674 +

Total : US$ 1,382,646 = Rp 19.932,563.429

Total harga peralatan = harga peralatan proses + harga peralatan utilitas

= US$ 1,895,073+ US$ 1,382,646

= US$ 3,277,718

= Rp 47.252.404.253

Prarancagan pabrik *Urea formaldehyde* didasarkan pada kebutuhan *Urea formaldehyde* untuk industri di Indonesia dan ketersedian bahan baku yang ada.Berdasarkan hal tersebut maka kapasitas dibuat berdasarkan ketersediaan bahan baku.

Kapasitas Produksi : 150.000 ton/tahun

: 20792,99 kg/jam

WaktuOperasipabrik : 300 hari

1.2 Perhitungan Komponen-Komponen Investasi

Perkiraan investasi dihitung dengan menggunakan faktor rasio berdasarkan metode *delivered equipment cost* untuk *liquid-liquid processing plant* seperti yang dapat dilihat pada Tabel D.4 di bawah ini.

Tabel D.4 Perhitungan *Capital Investment* Pabrik *Urea Formaldehyde* dari *Urea* dan *Formaldehyde*

Parameter	%	Biaya (US$)	Biaya (Rp)
Direct cost			
Biayaperalatan	100%	3,277,718	47.252.404.253
Pemasanganalat	47%	1,540,528	22.208.629.999
Instrumentasidanalatkontrol	18%	589,989	8.505.432.765
Pemasanganpipa	66%	2,163,294	31.186.586.807
Pemasanganinstalasilistrik	11%	360,549	5.197.764.468
Bangunan	18%	589,989	8.505.432.765
Pengembangan area	10%	327,772	4.725.240.425
Fasilitaspelayanan	70%	2,294,403	33.076.682.977
Lahan	6%	196,663	2.835.144.255
Total Direct cost		11,340,904	163.493.318.714
Indirect cost			
Engineering and Supervision	33%	1,081,647	15.593.293.403
BiayaKonstruksi	41%	1,343,864	19.373.485.744
Total Indirect cost		2,425,511	34.966.779.147
Total Direct Cost dan indirect Cost		13,766,416	198.460.097.861

Biayakontraktor	5%	688,321	9.923.004.893
Biayatakterduga	10%	1,376,642	19.846.009.786
Fixed Capital Investment		**15,831,379**	**228.229.112.540**
Work Capital Investment	15	**2,793,773**	**40.275.725.742**
Total Capital Investment		**18,625,151**	**268.504.838.282**

(Sumber : Peters, Tabel 17 Hal 183)

2. Sumber Investasi

Sumber investasi atau permodalan berasal dari modal sendiri dan modal pinjaman bank dengan persentase 50% - 50%.

- Modal sendiri = 50% xUS$18,625,151
  = US$ 9,312,575.68
- Pinjaman bank = 50% xUS$18,625,151
  = US$ 9,312,575.68

3. Biaya Produksi Total (*Total Production Cost*)

a. Biaya Bahan Baku

1. Urea

Kebutuhan : 5.940,25 kg/jam

Harga : Rp 5910,66/kg

$$Total\ harga = 5.940,25\ \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times Rp\ 5.910,66/kg$$

$$= Rp\ 252.797.852.993$$

$$= US\$\ 17.535.618$$

2. Formaldehid

Kebutuhan : 15974,46179 kg/jam

Harga : Rp 8649,75/kg

$$Total\ harga = 15.974,46179 \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times \text{Rp } 8649,75\ /\text{kg}$$

$$= Rp\ 994.860.726.250$$

$$= US\$\ 69.009.675$$

3. Buffer NaOH

Kebutuhan : 1.597,45 kg/jam

Harga : Rp 10.812,19/kg

$$Total\ harga = 1.597{,}45 \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times Rp\ 10.812/kg$$

$$= Rp\ 124.357.590.747$$

$$= US\$\ 8.626.209$$

4. Alum ($Al_2(SO_4)_3$)

Kebutuhan : 5,89 kg/jam

Harga : Rp 1.064 /kg

$$Total\ harga = 5{,}89 \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times \text{Rp } 1.064\ /\text{kg}$$

$$= Rp\ 45.104.764$$

$$= US\$\ 3.128$$

5. Kaporit ($Ca(ClO)_2$)

Kebutuhan : 5,89 kg/jam

Harga : Rp 11.967 /kg

$$Total\ harga = 5{,}89 \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times \text{Rp } 11.967\ /\text{kg}$$

$$= Rp\ 507.301.429$$

$$= US\$\ 35.189$$

6. Kapur tohor $Ca(OH)_2$

Kebutuhan : 4,42 kg/jam

Harga : Rp 1.436 /kg

$$Total\ harga = 4{,}42 \frac{kg}{jam} \times \frac{24\ jam}{1\ hari} \times \frac{300\ hari}{1\ tahun} \times \text{Rp } 1.436/\text{kg}$$

$$= Rp\ 45.655.856$$

$= US\$ \ 3.167$

Total biaya untuk pembelian bahan baku = US$ 95.212.988

= Rp 2.104.294.141.257

b. Gaji Karyawan

Daftar gaji karyawan pra rancangan pabrik *Urea Formaldehyde* dari *Urea* dan *Formaldehyde* dapat dilihat pada Tabel D.5 di bawah ini.

Tabel D.5 Daftar Gaji Karyawan

Jabatan	Jumlah	Gaji/Bulan (Rp)	Total/bulan (Rp)	Total/tahun (Rp)
Dewan Komisaris	2	33.730.750	67.461.500	809.538.000
Direktur utama	1	23.611.525	23.611.525	283.338.300
Direktur	3	20.238.450	60.715.350	728.584.200
Kepala bagian				
-S2 Teknik Kimia	2	16.865.375	33.730.750	404.769.000
-S2 Teknik Mesin	1	16.865.375	16.865.375	202.384.500
-S2 Manajemen	2	16.865.375	33.730.750	404.769.000
-S2 Akuntansi	2	16.865.375	33.730.750	404.769.000
Kepala seksi				
-S1 Teknik Kimia	1	13.492.300	13.492.300	161.907.600
-S1 Teknik Industri	1	13.492.300	13.492.300	161.907.600
-S1 Teknik Mesin	1	13.492.300	13.492.300	161.907.600
-S1 Manajemen	1	13.492.300	13.492.300	161.907.600
-S1 Akuntansi	1	13.492.300	13.492.300	161.907.600
-S1 Ilmu Komunikasi	1	13.492.300	13.492.300	161.907.600
Karyawan				
-S1 Teknik Kimia	2	10.119.225	20.238.450	242.861.400
-S1 Teknik Industri	2	10.119.225	20.238.450	242.861.400
-S1 Manajemen	5	10.119.225	50.596.125	607.153.500
-S1 Akuntansi	3	10.119.225	30.357.675	364.292.100
Sekretaris				
-S1 Manajemen	1	10.119.225	10.119.225	121.430.700
Kepala satpam				
-SMA	1	6.746.150	6.746.150	80.953.800
Sopir				
-SMK otomotif	3	6.746.150	20.238.450	242.861.400
Dokter				
-S1 Kedokteran	2	13.492.300	26.984.600	323.815.200

Perawat				
-D3 Keperawatan	2	8.095.380	16.190.760	194.289.120
Karyawan Produksi				
-D3 Teknik kimia	20	8.095.380	161.907.600	1.942.891.200
-D3 Teknik industri	16	8.095.380	129.526.080	1.554.312.960
Karyawan Utilitas				
-D3 Teknik kimia	4	8.095.380	32.381.520	388.578.240
-D3 Teknik lingkungan	5	8.095.380	40.476.900	485.722.800
Karyawan Mesin (teknisi)				
-D3 Teknik mesin	6	8.095.380	48.572.280	582.867.360
Karyawan laboratorium dan Pengendali Mutu				
a. Laboratorium proses				
-D3 kimia analis	4	8.095.380	32.381.520	388.578.240
a. Laboratorium pengendalian mutu				
-D3 kimia analis	5	8.095.380	40.476.490	485.722.800.
Karyawan Instrumentasi dan Elektrikal				
-D3 Teknik elektro	6	8.095.380	48.572.280	582.867.360
Satpam				
-SMA	6	6.746.150	40.476.900	485.722.800
Supervisor				
-S1 Teknik kimia	3	13.492.300	40.476.900	485.722.800
Office boy				
-SMA	6	6.746.150	40.476.900	485.722.800
Total	**121**			**14.498.825.580**

Maka, gaji total karyawan selama 1 tahun = Rp 14.498.825.580

= US$ 1005727,951

c. Perhitungan Komponen Biaya Produksi Total

Perhitungan komponen biaya produksi total dapat dilihat pada Tabel D.6 di bawah ini.

Tabel D.6 Perhitungan Komponen Biaya Produksi Total

Parameter	***Fixed Cost*(US$)**	***Variable Cost*(US$)**
Manufacturing Cost ***Direct Production Cost (DPC)***		
Raw Material		55.791.356
Operating Labor	1.005.727,95	

Direct Supervisory		100.572,80
Utilities		0,10 TPC
Maintenance and Repairs	474.941,36	
Operating Supplies	47.494,14	
Laboratory Charges		10.057.279,51
Total Direct Production Cost	1.528.163,45	65.949.208,79+ 0,10TPC
Fixed Charge (FC)		
Depresiasi	1.583.137,87	
Patent and Royalty	0,02 TPC	
Local Tax	158.313,79	
Insurance	63.325,51	
Total Fixed Charge	1.804.777,17 + 0,02 TPC	
Plant Overhead Cost		0,05 TPC
General Expenses		
Administrative Cost	0,02 TPC	
Distribution Cost	0,05 TPC	
Research and Development Cost	0,05 TPC	
Financing	372.503,03	
Total General Expenses	571.810,12+ 0,12 TPC.	
Total Production Cost	3.705.443,64+ 0,14 TPC	65.949.208,79 + 0,15TPC

Total Production Cost= Manufacturing Cost + General Expenses

= (*Fixed Cost* + *Variable Cost*)

TPC = (3.705.443,64 + 0,11 TPC)+ (65.949.208,79+ 0,15TPC)

= 69.654.652,43 + 0,26 TPC

0,74 TPC = 69.654.652,43

TPC = US$ 133.710.043

TPC = US$ 133.710.043= Rp 1.927.597.403.793

Sehingga :

- *Direct Production Cost* = US$ 110.139.155,72

  = Rp 1.587.793.603.591,02
- *Fixed Charge* = US$ 4.478.978,02

  = Rp 64.570.066.905,39
- *Plant Overhead Cost* = US$ 6.685.502,14

= Rp 96.379.870.189,65

- *General Expenses* = US$ 16.417.708,16

  = Rp 236.681.785.220,81
- *Fixed Cost* = US$ 18.239.403,18

  = Rp 262.943.796.068,29
- *Variable Cost* = US$ 115.470.639,57

  = Rp 1.664.653.607.724,08

4. Harga Penjualan Produk (*Total Sales*)

Tabel D.7 Perhitungan Komponen Biaya Produksi Total

Produk	Massa (kg/jam)	Massa (Ton/thn)	Harga/ton (US$)	Total Harga (US$)
UreaFormaldehid	20792,99	150.000	975	145.966.818
Total				145.966.818

(Sumber: www.amazon.com)

BerdasarkanTabel D.6 diperolehhargapenjualan (TS) sebesar US$ 110.313.720.

5. Analisa Kelayakan Investasi

5.1 Laba

- *Total Capital Investment* (TCI)= US$ 18.625.151
- Depresiasi = US$.1.583.138
- Total Penjualan Produk (TS) = US$ 145.966.818

  Total Production Cost (TPC) = US$ 133.710.043

Laba Sebelum Pajak (Laba Kotor) = Total Penjualan– Biaya Produksi

= US$ 145.966.818- US$ 133.710.043

= US$ 12.256.775,34

= Rp 176.696.737.464,28

Pajak 12.5% (Dirjen Pajak)

Laba Bersih = Laba Kotor – (Labakotor x Pajak)

= US$ 12.256.775,34- (US$ 12.256.775,34x 12,5%)

= US$ 10.742.678,42

= Rp 154.609.645.281,25

5.2 Laju Pengembalian Modal (*Rate Of Return*)

$$ROR = \frac{laba\ bersih}{TCI}\ x\ 100\ \%$$

$$= \frac{\text{US\$ 10.742.678,42}}{\text{US\$ 18,625,151}}\ x\ 100\%$$

$$= 57{,}58\ \%$$

5.3 Waktu Pengembalian Modal (*Pay Out Time*)

Masa *start up* : 2 tahun

Umur pabrik :10 tahun

Kapasitas produk pabrik selama beroperasi :

Tahun I : 70%

Tahun II : 90%

Tahun III dan seterusnya : 100%

Keuntungan masing-masing kapasitas setelah ditambah depresiasi

1. Kapasitas 70%

   = total penjualan 70% - [{*fixed cost* + (*variable cost* x 70%)}+ depresiasi]

   = US$ 1.524.783,92

2. Kapasitas 90%

   = total penjualan 90% - [{*fixed cost* + (*variable cost* x 90%)}+ depresiasi]

   = US$7.7624.019,62

3. Kapasitas 100%

   = total penjualan 100%-[{*fixed cost* + (*variable cost* x 100%)}+ depresiasi]

   = US$ 10.673.637,47

Jumlah keuntungan selama *start up* adalah= US$ 9.148.803,54

$$POT = 2 + \frac{TCI - jumlahkeuntunganselamastartup}{keuntungansaatkapasitas\ 100\%}$$

$$= 2 + \frac{\text{US\$ } 18{,}625{,}151 - \text{ US\$ \$ } 9.148.803{,}54}{\text{US\$ } 10.673.637{,}47}$$

$$= 2{,}8878 \; tahun$$

Maka diperoleh POT sebesar 2 tahun 10 bulan 20 hari

5.4 Titik Impas (*Break Even Point*)

Total Sales = US$ 145.966.818= Rp 2.104.294.141.257

Fixed Cost = US$ 18.239.403,18= Rp 261.943.796.068

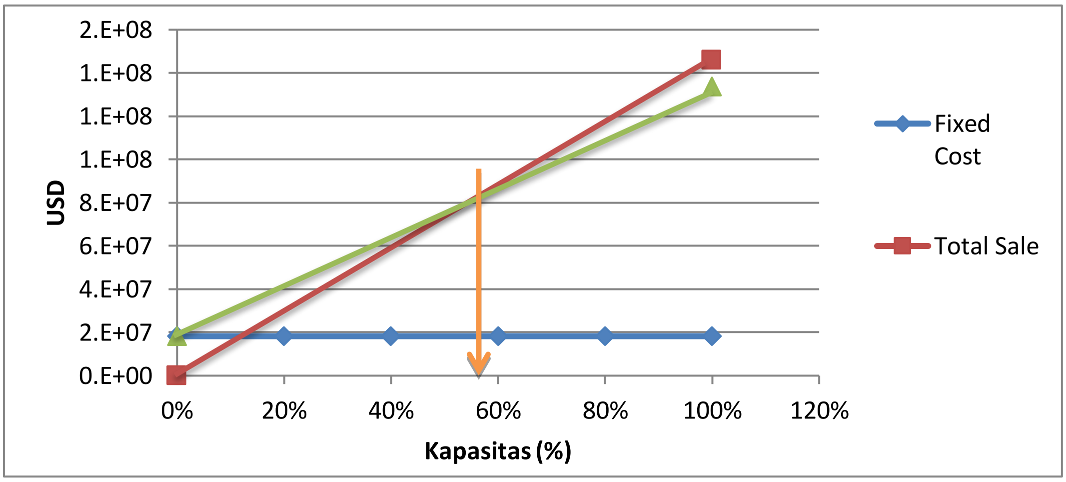
Variabel Cost = US$ 115.470.639,57 = Rp 1.664.653.607.725

Maka,

$$Break\ Even\ Point\ (BEP) = \frac{Fixed\ Cost}{Total\ Sales - Variabel\ Cost} x\ 100\%$$

$$Break\ Even\ Point\ (BEP) = \frac{18.239.403{,}18}{145.966.818 - 115.470.639{,}57} x\ 100\%$$

$$Break\ Even\ Point\ (BEP) = 59{,}81\%$$



Gambar D.2 Kurva BEP